ELECTRIC
ELEVATOR EQUIPMENT
FOR
MODERN BUILDINGS

A PRACTICAL GUIDE TO ITS SELECTION, INSTALLATION, OPERATION AND MAINTENANCE

BY

RONALD GRIERSON

Associate Member of the Institution of Electrical Engineers
Associate Member of the Institution of Mechanical Engineers

NEW YORK
D. VAN NOSTRAND COMPANY
8 WARREN STREET
1924

PRINTED IN GREAT BRITAIN
AT THE ABERDEEN UNIVERSITY PRESS
ABERDEEN, SCOTLAND

AUTHOR'S PREFACE.

THE object of this Work is to present to Engineers, Architects and others interested in the subject, in as simple and concise a form as possible, the general principles and practices connected with the selection, installation, operation and maintenance of Modern Electric Passenger, Goods, and Service Lifts, and Escalators. The available literature on the subject is extraordinarily meagre, and it is largely due to the suggestions received from the Librarians of various Technical Societies and Institutions that the book has been written. It is believed to be the first volume on electric lifts published in England.

The subject matter is based upon and has been expanded from a series of articles which appeared originally in the "Builder," and the author desires to express his sincere thanks to the editor of that journal for the assistance he has received from him from time to time.

Full advantage has been taken of the opportunity offered by the necessity of reprinting largely to rewrite and expand certain sections and to revise others, and it is hoped that the information in its present form may prove of real assistance to those who are called upon to accept responsibility in connection with electric lift equipment.

For much of the matter the Author claims no originality, the book consisting largely of notes, made at various times during the past fifteen years, from technical journals, books, newspaper cuttings, tests, trade catalogues, and other sources. Where possible, due acknowledgment has been made of the source from which the information has been derived, but if, through any oversight or inadvertence, an omission has occurred, suitable apologies are tendered.

Special thanks are due to Messrs. H. M. Harrison, B.Sc. (Techs.), H. Harmsworth, R. A. Evans, and H. Marryat for their courtesy in reading the proofs, and for their kindly advice and valuable suggestions.

R. G.

LONDON.

TABLE OF CONTENTS.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

CHAPTER XXIII.

CHAPTER XXIV.

APPENDICES.

BIBLIOGRAPHY.

(The Author's thanks are due to the undermentioned, to which reference has been made and from which, in some cases, valuable information has been utilized.)

"Electric Power Applications to Passenger and Freight Elevators" (*Reed: Trans. Am.I.E.E.*).

"Elevator Shaft Construction" (*Cullmer*).

"Mechanical Equipment of Federal Buildings" (*Thompson*).

"Elevator Service" (*Bolton*).

"Elevators" (*Jallings*).

"Elevator Safeties" (*Trans. Am.Soc.Mech.E.*).

"Passenger Elevators" (*Trans. Am.Soc.C.E.*).

"Results of a Survey of Elevator Interlocks and an Analysis of Elevator Accident Statistics" (*Oakes & Dickinson, U.S.A. Bureau of Standards*).

"Elevators; Care and Maintenance" (*Aetna Life Assurance Co.*).

MODERN ELECTRIC LIFT EOUIPMENT

CHAPTER I.

HISTORICAL.

THE gradual transition from the Chinese windlass, the rope tackle, the capstan and the ship's windlass, through the simple form of workshop hoist to the modern high-speed electric passenger lift is an interesting story of development rendered necessary by the increasing value of ground in certain localities, and a corresponding growth in the heights of the buildings erected thereon.

Mr. Harrison P. Reed mentions [1] that Vitruvius described an elevator built by Archimedes in the year 236 B.C., and that, according to Professor Coburn of Philadelphia, who has made extensive archæological studies in Palestine, the palace of Nero contained three lifts.

It has also been stated that Professor Commadatore Boni, a celebrated Italian archæologist, while exploring some underground passages near the north rostra of Caesar, discovered twelve small galleries which he claims are traces of a former system of lifts, as in each room there are grooves through which ropes passed, and stone supports for wooden poles (? guides) are fixed vertically inside the passages.

Mr. Reed further states that Napoleon I. mentioned a lift in a letter to his wife, the Archduchess Maria Louise.

A Brussels paper, not long ago, mentioned that Velayer of Paris invented, in the seventeenth century, an ingenious contrivance which he called a "flying chair." It apparently consisted of a chair supported by a rope passing over a pulley and was counterbalanced by a weight. It is said to have been very popular among the rich people on account of its utility. Apparently safety gear was not fitted, for it is recorded that a serious mishap occurred to the King's daughter, as a result of which it fell into disfavour.

[1] "Electric Power Applications to Passenger and Freight Elevators," *Trans. Am. I.E.E.*, Jan., 1922.

Mr. T. E. Browne mentions[1] an early form of water-balance lift installed in the Western Union Building in New York which survived until a few years ago. This elevator consisted of a car, suspended by cables passing over a sheave at the top of the building and attached to an iron bucket weighing less than the car. At the will of the operator, the bucket could be filled with water or emptied by a hand cable attached to a water-supply valve at the top of the building, and to an exhaust valve in the bottom of the bucket. When sufficient water was admitted to the bucket to overbalance the car and its load, the bucket descended and the car ascended, and when the water was allowed to discharge from the bucket the car descended.

In 1878, according to the same authority, Mr. Cyrus W. Baldwin installed the vertical cylinder type of hydraulic elevator in the Boreel Building in New York, and since that date the race has continued between the architect, the builder, and the structural engineer on the one hand, and the lift engineer on the other.

The credit for the first successful application of electric power to lifts apparently belongs to Mr. William Baxter, Jun., who invented a lift operating on constant current in the year 1884 and installed it in a building in Baltimore, U.S.A., in 1887.

In 1885 Mr. Schuyler S. Wheeler took out a patent for an electric elevator, in which it was proposed to use constant potential, shunt motors and magnetic brakes, general features now used universally.

In 1889 Mr. Norton P. Otis, in conjunction with Messrs. Rudolph Eickemeyer and R. C. Smith, designed an electric lift of the drum type, two of which were installed at Fifth Avenue and Thirty-third Street, New York. This lift was successful and other installations followed rapidly. It is interesting to note that in these machines the motor was of the compound wound type, and was directly connected to a worm shaft, so that they differed from the modern drum type machine only in minor details and in the electrical control.

Mr. Frank Sprague brought out the long screw electric elevator machine fitted with his well-known pilot motor control

[1] "Passenger Elevators," *Trans. Am. Soc. C.E.*, vol. liv., Part B, 1905.

Note.—Mr. H. Marryat of Messrs. Marryat & Place has kindly informed me that he installed in Regent Street, London, in 1889 or earlier, a traction drive lift with 200 volt d.c. compound wound motor, overhead gear, and hand rope controller. Mr. Marryat states that this lift was not unique at the time, and that it is still running.—AUTHOR.

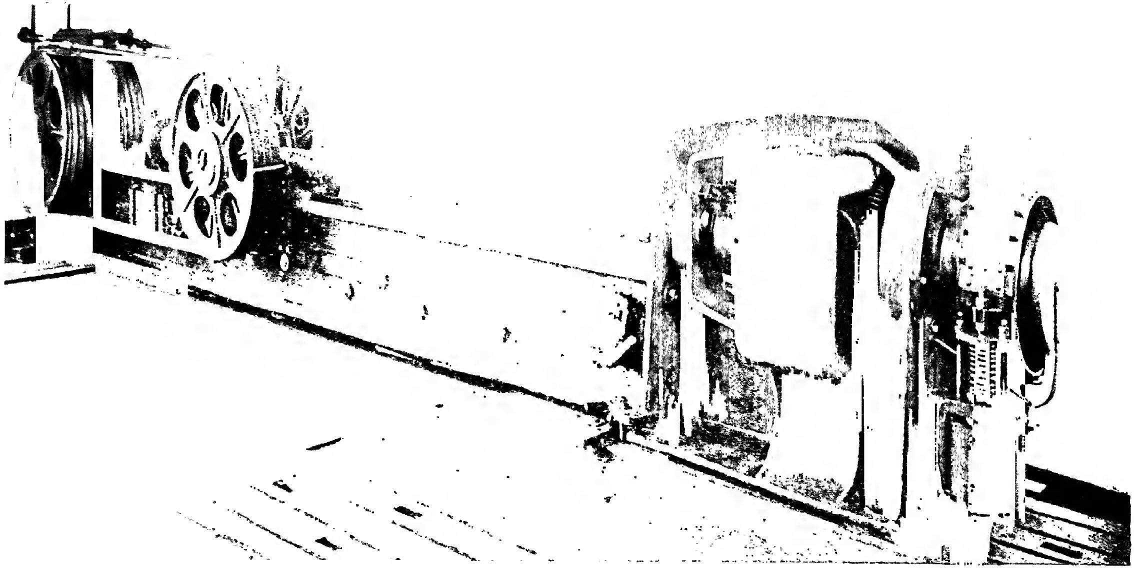


FIG. 2.—Sprague long screw electric elevator engine.

[By the courtesy of the Am. Soc. of Civil Engineers. Brochure on "Passenger Elevators".]

[To face p. 2.

(Fig. 2) in 1894, but due to various causes its manufacture has been abandoned.

Mr. John D. Ihlder designed the first "Magnet Control System" in 1897, in which he connected the electro-magnets of the switches, controlling the starting resistance, across the armature of the lift motors and utilised the rising voltage, due to the increase in speed of the armature, gradually to cut out the starting resistance and finally the series field.

In 1899 the Sprague Elevator Company installed the lift equipment for the Central London Tube, the cars being designed for a load of ninety persons or 14,000 lbs. each. The engines are of the tandem worm-geared type, two complete sets of gearing, each driven by its own shunt wound motor, being coupled to the drum.

To eliminate the difficulties that are experienced if an endeavour is made to employ a drum type winding engine in a high building, Mr. E. M. Fraser invented, in 1899, the double motor, continuous running, rope drive elevator, and installed equipment of this type in San Francisco, and later in Chicago and New York. This machine, which is the early type of the traction drive engine, is fully described in Chapter IX.

CHAPTER II.

ESTIMATING SERVICE REQUIREMENTS.

1. Horizontal and Vertical Transportation.—Modern electric passenger lift practice in large buildings will, if analysed, be seen to resemble, in miniature, a suburban surface railway, a tube railway, or a tramway serving two or more stations or stopping places, the main differences being that the direction of travel is in a vertical instead of a horizontal direction, the stations or floors are nearer together, the service is, or should be, better (i.e. the time interval between the departure of successive cars is shorter), and the number of passengers entering and leaving the cars at intermediate stations or floors is usually smaller.

If the number of cars is insufficient to carry the number of passengers who desire to travel, or the cars are large and carry a considerable number of passengers, but have in consequence to stop at each floor on the up trip, and at each floor on the down trip, it is apparent that in the first case a considerable number of people will use the stairs rather than wait if their destination is not far up; and, in the second case, that the service will be so bad that many people will be kept waiting for an unreasonable length of time, or will become impatient and will also walk. In either case, it is obvious that there will be reasonable cause for complaints, and tenants on the higher floors will either seek accommodation elsewhere, which is more conveniently situated, as regards time from the street, or demand lower rentals, due to the inconvenience. When the cars carry the number of people that arrive at, or depart from, the building in a given time and distribute them on the various floors or bring them to the street level, then the service may be considered 100 per cent. of that required. The limiting point in the carrying capacity of any passenger lift is reached when certain combinations of passengers carried and floors to and

from which they are carried occur, and it is now proposed to examine these factors in detail.

2. Operating Cycle.—The daily or hourly work of an electric passenger lift consists of a definite cycle of operations many times repeated, the complete cycle being termed "a round trip." The number of round trips per hour per car obviously depends on the time required for one trip, and this again depends on a number of factors.

The cycle of operations for a two-floor lift starting from rest at the ground floor and carrying passengers in one direction only may be roughly classified as follows:—

(*a*) Passengers enter the car at the ground floor.
(*b*) Landing doors closed.
(*c*) Car gate closed.
(*d*) Car accelerates from rest to maximum load speed.
(*e*) Car runs at maximum load speed.
(*f*) Car approaches first stop and slows down from maximum load speed to rest at top floor.
(*g*) Car gate opened.
(*h*) Landing doors opened.
(*i*) Passengers leave car.
(*j*) Landing doors closed.
(*k*) Car gate closed.
(*l*) Car accelerates from rest to maximum load speed.
(*m*) Car travels at maximum load speed in downward direction.
(*n*) Car approaches ground floor and slows down from maximum load speed to rest at the ground floor.
(*o*) Car gate opened.
(*p*) Landing door opened.

3. Car Speeds.—In determining the speed of passenger lift cars, due consideration should be paid to the size of the car, the total height of travel, the landings served, the method of operating the cars, i.e. express or local, the method of control to be employed, the cost of electrical energy, and the amount available for the motor since high car speeds involve powerful and expensive motors and increased power bills.

Mr. Harrison P. Reed indicates that the following data may be regarded as representative of modern American practice for office and similar buildings equipped with direct-current motors:—

TABLE I.

CAR SPEEDS (REED).

Total Travel (ft.).	Max. Car Speed (ft./min.).
0-50	50-300
50-75	300-350
75-100	350-400
100-150	400-500
150 up	400-550

Mr. Nelson S. Thompson recommends[1] the following speeds :—

TABLE II.

CAR SPEEDS (THOMPSON).

Type of Building.	Max. Car Speed (ft./min.).
Flats	200 ft./min.
Department stores	250 ,,
Office buildings—	
up to 10 floors	200-400 ft./min.
10 to 15 floors	400 ft./min.
Government buildings—	
30 to 40 ft.	200 ,,
45 to 70 ft.	250 ,,
75 and over	300 ,,

For express service, i.e. a non-stop run of 80 ft., a car speed of 550 to 600 ft. per minute is commonly employed.

For large departmental stores of the Oxford Street and Kensington (London) type 250 ft. per minute is about the accepted average speed, since the cars usually stop at each floor both on the upward and on the downward trip.

Single-speed controllers are, as a rule, fitted to cars travelling at all speeds up to 200 ft. per minute, two-speed controllers up to 300 ft. per minute, and three-speed controllers above that speed. It will therefore be noted that not only do high-speed cars involve more expensive motors but also that the control gear necessarily becomes more elaborate.

For cars fitted with the single speed type of automatic push button controller only, a speed of 160 ft. per minute is usually regarded as the maximum. (See also Appendix, "Typical Installations of Modern Lifts.")

[1] *Mechanical Equipment of Federal Buildings.*

It should be noted that high-speed cars used on local service are liable to be costly to operate since they spend nearly as much time in accelerating and retarding as they do in running at full speed, and each time the car starts the motor armature, car, counterweights, cables, etc., must be accelerated from rest.

Few methods of control return the kinetic energy stored in the moving parts (which for a given mass is proportional to the *square* of the velocity) to the line, it being almost invariably dissipated in the form of heat, either in the resistance coils of the dynamic brake or in the shoes of the magnetic brake.

4. Time Required for the Round Trip and Number of Trips per Hour.—Many people have apparently held the view hitherto that a high load speed meant quick service under all conditions, but consideration of the sixteen factors, constituting the cycle of operations, scheduled in paragraph 2, will indicate quite clearly that this is not necessarily the case. In fact, if the car is large and the stops very near together the operations of acceleration and retardation of speed will cover the distance travelled, and the car may seldom actually travel at maximum speed. Similarly, an indefinite increase in the passenger capacity of the car may in certain circumstances actually reduce the total number of passengers carried per hour.

Observations have been made in many hundreds of installations, and the following average figures have been obtained which enable time schedules to be calculated that will give reasonable accuracy in practice:—

(*a*) *Time required to open and close landing doors.*—This depends upon the strength of the attendant, the accessibility of the door latch, ease of motion, and width of doors; average $1\frac{1}{2}$ to 3 secs.

(*b*) *Time required to open and close car gate.*—This also depends on factors as above, and averages $1\frac{1}{2}$ to 3 secs.

(*c*) *Time required for passengers to enter and leave the car.*—This depends upon age and experience of passengers, shape and size of car, number of people in car, etc. This averages $1\frac{1}{4}$ to 6 secs., but is usually taken as 2 secs. for the combined operation.

(*d*) *Time required for passengers to enter or leave car at intermediate landing.*—Including doors and gates this is usually taken as 6 secs.

(*e*) *Landing stops.*—These are usually assumed to be 0·4 of the floors served in each direction. Thus, in a five-floor building there would be two stops on the up and two stops on the down journey, or $5 + 5 = 10$ and $10 \times 0{\cdot}4 = 4$ stops.

(*f*) *Mean speed.*—This is frequently assumed to be 80 per cent. of maximum speed, but, of course, this depends upon the value of the maximum speed and the distance apart of the stops. Thus, a car travelling from floor to roof at a speed of 10 ft. per sec. would, if the run were to be made up of a series of stops and starts 16 ft. apart, attain a mean speed of only about 6 ft. per sec., i.e. 60 per cent. of the maximum speed. The time required for acceleration and for retardation frequently averages from 3 to 6 secs., depending on the load speed.

Example.—Assume a ten-floor building—i.e. four passengers up and four down; maximum speed, 300 ft. per min.; height = 120 ft. Then time required for round trip is:—

(*a*)	Four passengers enter and four leave at the ground floor, at 2 secs. each	8 secs.
(*b*)	Close and open landing doors at ground floor, at 2 secs. each	4 „
(*c*)	Close and open car gate, etc.	4 „
(*d*)	Eight landing stops, at 6 secs. (four on up and four on down journey)	48 „
(*e*)	Travel time for 240 ft., at 80 per cent. of 300 ft.	60 „
	Total time	124 „

Trip time = 2 mins. 4 secs., and trips per hour = 29. Passengers handled per hour:—

Up	116
Down	116
Total	232

It will be observed that, if the basis of calculations is that shown above, when tenants arrive in the morning the car can call at 80 per cent. of the floors on the upward journey and make a non-stop journey down without materially affecting the time schedule. Similarly, in the evening, the car will make a non-stop trip on the upward journey, and will call at 80 per cent. of the floors on the down trip (see Fig. 3). These figures only represent average conditions since the human element of the passengers enters largely into the calculation.

Another method of figuring the time required for the trip assumes that 27½ secs. should be allowed for accelerating and retarding the car and loading and unloading at the ground floor, and that 7 to 8 secs. will be required for accelerating and retarding the car and loading and unloading at each landing stop above the ground floor. The number of stops per car mile is based on the assumption that in office buildings up to

eight stories it will average 150 to 200, and above that 125 to 175 for local service. For express service it is found to average from 50 to 150 stops, depending upon whether service

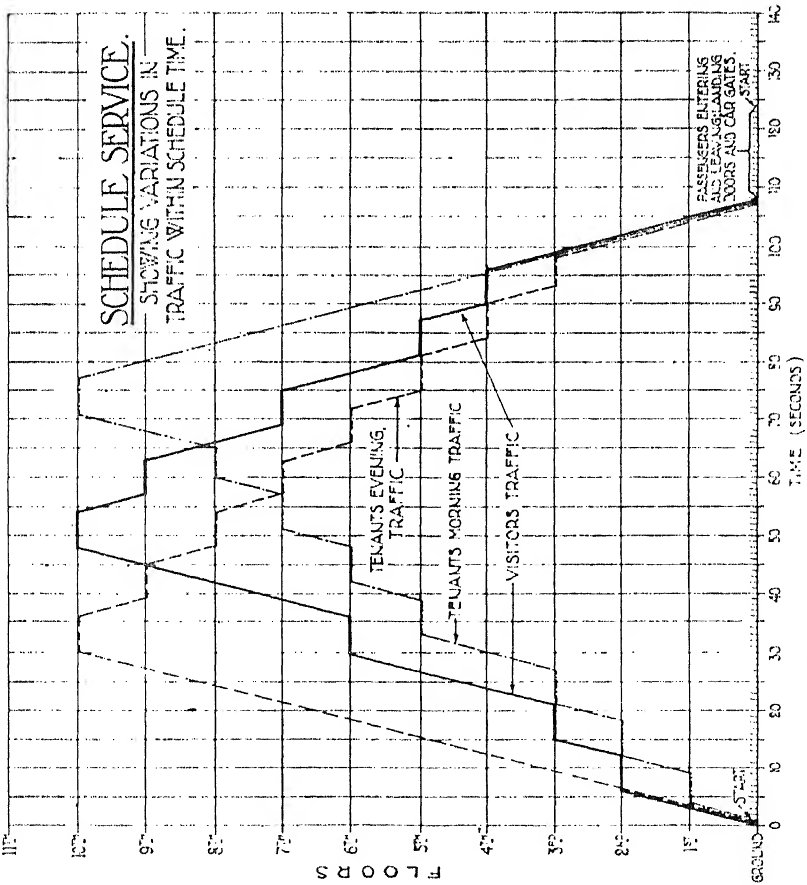


FIG. 3.—Schedule service, from *Elevator Service* (Bolton).

is given to several upper floors or only to a restaurant or club on one floor. The round time trip of a lift should not exceed, as a general rule, 2½ mins., but will be found to vary between 1½ to 3 mins., depending on height of building, speed, etc.

Time schedules are materially affected by safety appliances, such as door and gate locks, car gates, etc., as the time for loading and unloading is inevitably increased. It follows, therefore, that the extension of safety appliances tends to increase the number of cars installed. This is unfortunate, but the safety consideration is the all-important one.

5. Traffic Estimates and Number of Cars Required.—Lift traffic, unlike 'bus, tube, tramway, and suburban railway traffic, cannot be almost indefinitely expanded to meet rush hours by adding additional cars, as it is only possible to run one car in one shaft, or between one set of guide rails. Fortunately for lift engineers, abnormal rush traffic is not frequently encountered, and normal requirements which recur daily can be calculated with a fairly close degree of accuracy. The work of the lift is the carriage of passengers, and the passengers are either tenants or visitors. The number of visitors per hour is irregular, and they are less insistent upon immediate transport than the tenants. Therefore, an estimate of probable tenancy provides in the majority of cases the means of ascertaining the maximum rate of travel which takes place at the time of their arrival and departure.

Generally speaking, the following figures will provide a very fair basis for calculating the maximum traffic to be handled in any given class of building:—

TABLE III.

OCCUPIED FLOOR AREA.

Type of Building.	Sq. ft. of Occupied Floor Area per Occupant.
Cinema theatres, from	6 sq. ft.
Cafés and restaurants, from	12 ,,
Stockbrokers, engineers, etc., employing clerks, draughtsmen, etc.	75 to 100 ,,
Banks	120 ,,
Family hotel	200 ,,
Modern hotel	250 ,,
Flats	300 ,,

Frequently the occupied area of a modern office building will be found to average 60 per cent. of the gross area.

Other factors which will influence the hourly traffic of the lifts either in one or both directions are: Restaurant on one floor used by tenants; club or exclusive restaurant which the tenants' employees do not patronise; toilet rooms grouped on

a single floor; basement and sub-basement floors which do not form part of the scheduled time-table; residential flats on upper floors, etc.

Example.—Take an office building of ten floors above the ground standing on a site 100 ft. by 50 ft. = 5000 sq. ft. per floor, or a total of 50,000 sq. ft. of floor space, and allow 100 sq. ft. per tenant, i.e. 500 tenants. The majority will probably arrive and leave within a period of 30 mins., and the traffic

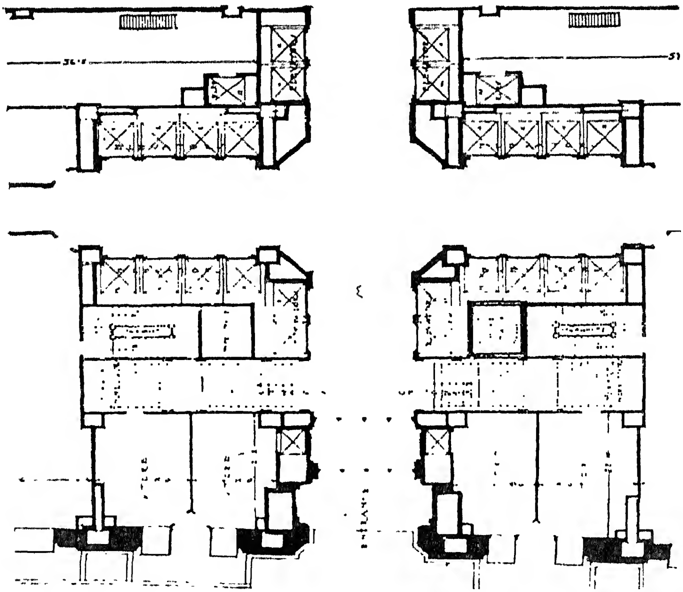


FIG. 4.—Elevator hall, ground floor, Woolworth Building, New York City, U.S.A. (*By the courtesy of "The Architect's and Builder's Journal."*)

to be handled is at the rate of 1000 per hour. Assuming the lift referred to in the previous paragraph be installed as a unit, this will handle 232 passengers per hour, and, therefore, a minimum of four lifts are indicated, but preferably five should be installed to admit of one being laid off for repairs without seriously affecting the time schedule. If four lifts are installed, the time schedule (i.e. the period of time between the dispatch of cars) will be 31 secs., and if five cars are installed the time

schedule will be 25 secs. approximately. This would be considered quite satisfactory, as experience indicates that business people object to waiting more than 30 secs. Another factor which must be taken into account in deciding the number of lifts to be installed in high buildings, is that of extricating the occupants from the upper floors within a reasonable space of time in the event of fire.

6. Grouping of Cars.—Experience shows that maximum efficiency is attained by grouping the lifts together in one part of the building near the main entrance so that the operators may be placed under the supervision of a "starter" or dispatcher. Elevator halls are a feature of all modern American office and hotel buildings, locals being grouped on one side and expresses on the other (Fig. 4). At least one car should be arranged with back gearing to lift heavy safes which ordinarily will not exceed 6000 lbs. For an exhaustive study of this subject reference should be made to *Elevator Service* (Bolton).

CHAPTER III.

PASSENGER CARS.

1. **The Shape and Size of the Car.**—In many existing buildings it is apparent that the size and the shape of the car was determined after practically every other constructional point was settled, and the efficiency of the lift service and the rental value of the upper floors has thereby been seriously impaired since the size and shape of the car are most important details in the time schedule. The narrow and deep car, the car with the narrow entrance and wide interior, and similar types need only to be mentioned to enable their bad points at once to be appreciated, and to suggest immediately the wide, shallow car for practically all lift work. Except for tube railway lifts, straight-through cars (i.e. cars with two entrances opposite to each other) should be avoided, as this arrangement entails the attendant leaving his car switch and possibly forcing his way through a crowded car in order to reach and to open the opposite gate and doors at an upper landing. Self-closing and self-opening doors can be provided when the straight-through car is unavoidable, but the extra cost quoted recently was approximately £200 per lift on an installation estimated at £1200.

The floor area of the car is determined by the required carrying capacity of the car, and in this connection it should be noted that with the single entrance each passenger must turn round once during the trip in order to face the landing.

An allowance of 2 sq. ft. per passenger and 4 sq. ft. for the attendant (to enable him to handle the controller, car gate, and landing doors rapidly) is the usual basis for figuring car capacity; e.g.: a car having a floor area of 6 ft. by 5 ft. = 30 sq. ft. would have a passenger capacity of 30 less 4 = 26, which, divided by 2 gives 13 passengers.

The weight of the average individual has been ascertained to be 140 to 150 lbs., and, therefore, the assumed load is figured at 75 lbs. per sq. ft. of floor area.

Convenient car sizes are as follows :—

TABLE IV.

CAR SIZES.

Depth.	Width.	Area.	Passengers.	Attendant.	Total.	Live Load.[1]
6 ft.	7 ft.	42	19	1	20	3150
5 ft.	6 ft.	30	13	1	14	2250
4 ft. 4 ins.	6 ft.	26	11	1	12	1950
4 ft.	5 ft.	20	8	1	9	1500
3 ft.	4 ft.	12	4	1	5	900

In modern office buildings up to ten floors a very useful size for the car is 5 ft. wide by 4 ft. 4 ins. deep (i.e. 21·5 ft. super., carrying eight to nine passengers). Large departmental stores of the Oxford Street, Regent Street, and Kensington type generally require a larger car, and in this case the size is frequently 8 ft. wide by 6 ft. deep, giving a floor area of 48 sq. ft., and designed for a maximum load of 3600 lbs. With these exceptions a 6 ft. by 6 ft. car is generally regarded as the largest standard car, rated for sixteen passengers and a gross load of 2700 lbs.

Every effort should be exercised to make the car as light as practicable, consistent with strength and rigidity, in order to reduce the load on the machine bearings and also the power consumption.

2. Types of Car and Car Details.—The floor space required and the arrangement of openings having been decided on the lines suggested in paragraph 1, the next point for consideration is the general design of the car and the material of which it is to be made.

Hitherto English practice has favoured hard-wood almost exclusively or a wainscot of wood to a height of 4 ft. surmounted by a wrought-iron cresting, the top being left open or covered as desired (Figs. 5 and 6).

Wood cars are most frequently made of basswood, American oak, mahogany, or teak, the former being the cheapest and the latter the most expensive (Figs. 7 and 8).

American practice, on the other hand, favours steel frame cars, both for the ordinary and the more expensive types of buildings, as they can be designed and finished to suit all tastes, and either painted or electro-bronze plated. For special work

[1] The term "live load" used in connection with lifts refers to the persons, animals, or goods carried in the car.

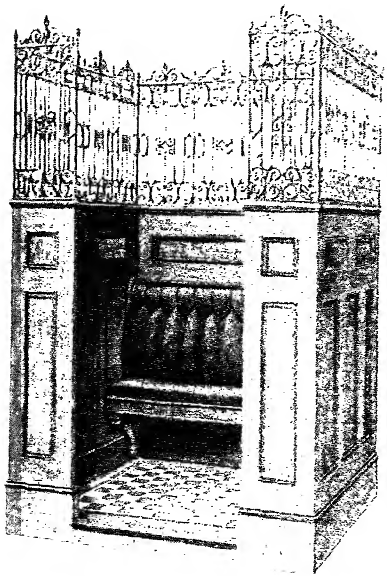


Fig. 5.—Hard-wood car with wrought-iron cresting and seat.

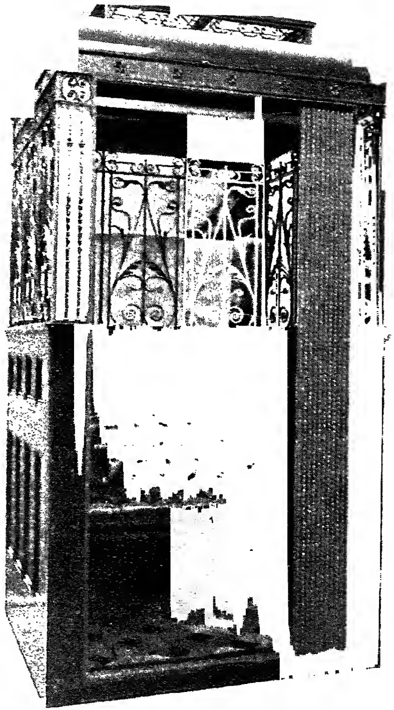


Fig. 6.—Hard-wood car with wrought-iron cresting and domed roof.

[To face p. 14.

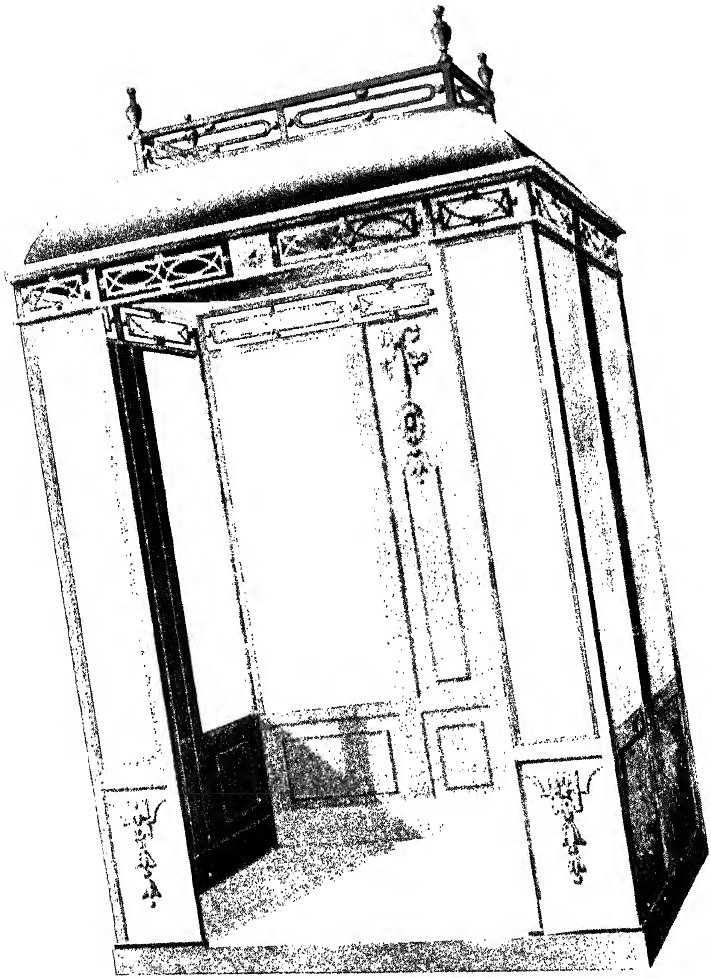


FIG. 10.—Steel-frame car with glass panels (incombustible).

[To face p. 15.

bronze is used, and this can, of course, be plated in any colour, but architects usually prefer to leave it in its natural colour (Figs. 9 and 10).

Grille work, where used, should be designed to prevent the passage of a hand or arm, but where a more open design is required danger can be eliminated by the use of plate-glass panels or fine-mesh wire. In New York City the Elevator Regulations do not permit more than 1 in. of space between the bars or mesh-work where scroll-work is not used, and not more than $1\frac{1}{2}$ in. between the bars or mesh-work where scroll-work is used.

The open-top type of car (Fig. 5) is more suitable for hot countries than for high-speed work in the British Isles, but it has the merit of cheapness where first cost is of prime importance. In addition to the draught objection, there is no protection for passengers from oil leakage from the overhead gear or engine, which it is almost impossible to avoid, and from objects which may be accidentally dropped down the shaft. When used, the lower wood wainscot should be carried to a minimum height of 4 ft. above the platform. If the height is less there is a considerable risk of passengers, both young and old, absent-mindedly slipping fingers or hands through the bars or mesh-work, and possibly suffering injury by accidental contact with counterweights, landings, etc., when the car is in motion.

In the enclosed type of wood and metal cars mirrors are very popular, but seats are not frequently fitted in modern lifts as they occupy valuable floor space. Where a seat is considered desirable, it should be of the hinged type, so that it may be folded up during periods of heavy traffic (Figs. 5 and 8).

In the more expensive types of buildings where cars are to be installed in the wells of main staircases it will probably be found desirable to specifiy moulding and polishing for the outside and also for the bottom of the car in addition to the interior. Overhanging external mouldings should be avoided, as they reduce the floor space in the car, and hence the passenger accommodation.

American Elevator Regulations, in many cities, call for escape doors to be fitted in the canopy, or, where two or more cars run in one shaft, means of exit may be provided in the side of the cars for use in the event of emergency (Fig. 11).

Emergency telephones or call bells are also occasionally fitted in cars running in enclosed shafts, so that in the event of anything unusual occurring the car conductor or operator can obtain assistance without loss of time.

Electric light fittings, with the necessary connections, are frequently regarded by makers as an extra, and, where required, should be definitely specified.

The standard floor finish for the car is either linoleum or $\frac{1}{2}$-in. compressed cork, complete with chequered brass nosing, finished flush with the cork.

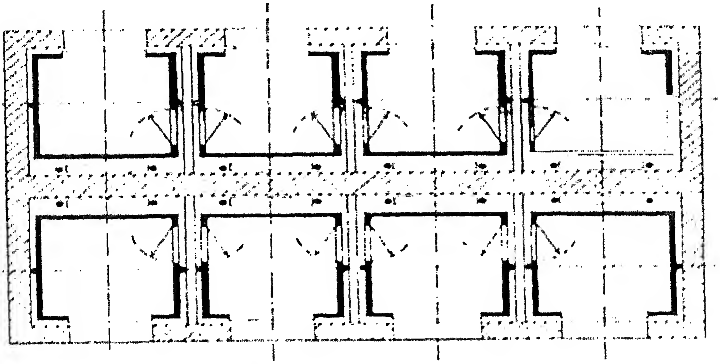


FIG. 11.—Battery of eight lifts, showing escape doors between cars.

3. Collapsible Car Gates.—Collapsible gates, formed of $\frac{1}{2}$-in. steel bars, top hung, complete with top and bottom tracks and electrically and mechanically interlocked in such a manner that the car cannot move until the gate is closed and latched, are strongly recommended for all car openings. In the absence of a gate it is always possible for a passenger's shoulder, head, foot, etc., to be caught on a floor or ceiling, resulting in a severe blow or perhaps a serious accident. The objection to their use is increased capital cost (very small), reduction of width of opening, and increase in the time required for the round trip (due to the additional time absorbed at each stop in opening and shutting the gate), and additional weight of the car. Actually a $\frac{1}{2}$-in. picket gate 5 ft. wide when extended weighs about 5 lbs. per sq. ft., and occupies a space, when collapsed, of $6\frac{1}{2}$ ins. in width and is $1\frac{5}{8}$ in. thick (Fig. 12).

For use in schools, children's hospitals and similar purposes an improved type of collapsible gate is available in which the spaces are reduced and danger is thus practically eliminated (Fig. 13). It is interesting to note in this connection that the London Underground Railway lift gates have now been fitted with short iron bars to prevent passengers putting their feet through the spaces.

4. Threshold Illuminator.—The threshold illuminator is rapidly becoming popular. This consists of a bronze threshold, having glass discs on the top and on the vertical face in the shaft through which a diffused light is thrown, illuminating the landing, and showing the relative position of the car floor to the sill of the door. These illuminated thresholds are, without doubt, extremely useful in preventing accidents due to careless floor levelling, and, since they serve to draw attention to any step, either up or down, which may be formed between the car platform and the landing, they are suitable for installation in all large stores, hotels, flats, etc. (Fig. 14).

At the request of the U.S.A. Bureau of Standards[1] a list of tripping accidents was prepared by one of the largest casualty insurance companies, the list including all tripping accidents occurring on lifts insured by them during the year 1919. An analysis showed that more tripping accidents occurred when the car platform was within 3 ins. of the landing level than occurred when the car platform was more than 3 ins. away. In other words, a 3-in. stopping range would not have prevented the majority of these accidents. The deduction drawn from this analysis was that threshold illumination was an important consideration in preventing tripping accidents and should be given careful consideration, if such accidents are to be avoided (see also "Car Levelling Devices," Chapter IX.).

5. Weight of Cars.—It is difficult to give any reliable figures for the weight of cars as this varies so much with the design. As a guide, for figuring loads on walls, etc., the following may be used, but they should be regarded as subject to confirmation by the maker selected :—

TABLE V.

WEIGHT OF CARS AND CAR SLINGS.

Floor Area (ft.).	6 × 7	5 × 6	4 × 6	4 × 5	3 × 4
Weight (lbs.) empty	2110	1570	1265	1120	950
,, ,, loaded	5050	3670	2945	2520	1850

6. Car Notices.—It is desirable to fix in each car a tablet, 3 ins. × 2 ins., stating the maximum number of passengers, and

[1] "Results of a Survey of Elevator Interlocks and an Analysis of Elevator Accident Statistics," C. E. Oakes and J. A. Dickinson.

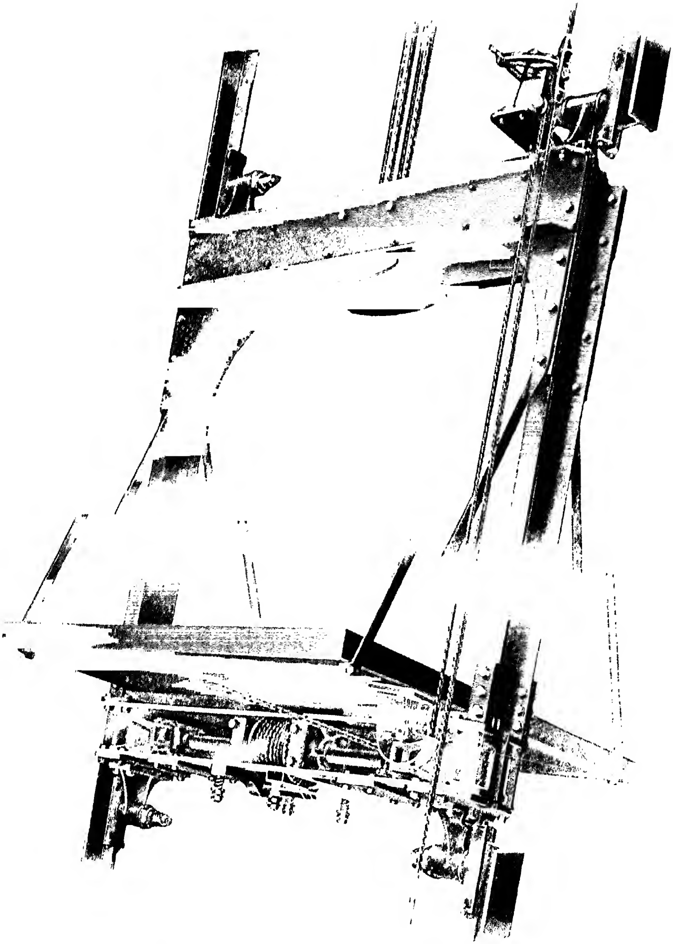
the equivalent weight, the car is designed to carry, in order to fix responsibility for overloading, should it occur.

The Aetna Life Insurance Company of Hartford, U.S.A., issue a useful printed card of instructions to passengers to be fixed in the car, and reading as follows :—

Passengers

for their own safety

Should not
- Get on or off a car while it is in motion.
- Get into the car when same is crowded.
- Stand near to or with back against the entrance.
- Touch operating apparatus.
- Talk to or interfere with the operator.



[*By the courtesy of the Otis Elevator Co.*

[*To face p. 19.*

CHAPTER IV.

CAR SLINGS AND SAFETY GEAR.

1. **Types of Car Sling and Platform.**—In the modern type of construction adopted by all the leading makers the car is regarded as an entirely separate unit, and is placed upon a platform that is carried by the ropes, by means of a steel sling or frame (Fig. 15). This sling must be of ample strength and rigidity, so that no strain can, under any circumstances, be thrown on the cabinet work due to any unsymmetrical loading of the floor or other cause. In addition to its function as the car support, the sling is also arranged to carry the car safety gear and the guide shoes or lugs that engage the guide rails or runners and are the equivalent of the wheels of an ordinary railway coach or tramcar running on a horizontal track. The designs for the car sling, safety gear, and guide shoes adopted by leading makers differ considerably, and, generally speaking, there is little to choose between them. It will be realised that it is impossible to describe the features of each design in detail in the space available, but if the fundamental features are discussed no difficulty should be experienced by the architect or the engineer in selecting suitable equipment to meet the requirements of any installation in which he may be interested.

The essentials of any type of car sling or frame are a top main suspension beam or bar of steel by which it is lifted, two steel vertical posts or styles, and a bottom cross-beam that carries the platform, all securely riveted together, to form a rectangular framework. By using steel channels for both styles and the top main suspension bar, and by employing two bottom beams made of channel steel also, an exceedingly strong frame can be constructed. Frequently for the ordinary sizes of cars the bottom channel beams are omitted and heavy wood or round bar construction is adopted. It will be clear also that the vertical styles and the top suspension beam may be formed of one length of channel steel, bent to shape, and, that within limits, equally good results may be obtained.

Details of platform construction depend on the arrangement of the guide rails. Where side guide rails are used then the problem is comparatively simple, as it resolves itself into one of two beams supported at the centre (on the vertical styles) and at either end (by stay rods), more or less uniformly loaded by decking and passengers. On the other hand, if cross corner guide rails are necessary, then the problem becomes more complicated, as it means that a rectangular or square floor has to be carried on one diagonal beam, which, from a mechanical point of view, is not a desirable arrangement. For small lifts, ample strength can be obtained by framing the platform in steel and utilising double channels for the lower beam, but for large cars secondary top and bottom beams, with tie rods, arranged on the other diagonal must be employed. At best a cross corner sling is but a makeshift, used only where it cannot be avoided. Any unsymmetrical loading of the car has a tendency to rock or twist the top main suspension beam, which should be made heavier, and hence this type of sling is usually more expensive.

2. Guide Rail Shoes.—Four guide shoes are almost invariably used and are secured to the car sling at the upper and lower corners. The actual design of the shoe naturally depends on the shape of the guide rail. In its simplest form, when used in connection with a wood guide rail, it is of cast-iron channel shape. For modern steel guides, self-acting, spring-loaded, gunmetal guide shoes are used (Fig. 16).

3. Early Types of Safety Gear.—The safety gear fitted to passenger lifts is of the highest importance both to passengers and to manufacturers, and while the latter have devoted great attention to the improvement of the efficiency of the plant the essential element of safety has not been lost sight of.

Originally, when one or two ropes were employed to support the car, there was obviously a very real danger of the car falling to the bottom of the shaft in the event of failure of either one or both of the ropes. Under these circumstances, designers applied themselves to the provision of a device that would hold the car and prevent its further descent should the rope break, and in view of the low speeds employed at that time, positive quick stops were not deemed to be very objectionable.

Up to about the year 1880 cast-iron racks or ratchets were attached to the guides, and a pair of dogs, fixed at the top of the car, attached to the single suspension rope, and operated by springs, formed the safety gear. When the rope failed, the springs that operated the dogs engaged with the racks on the

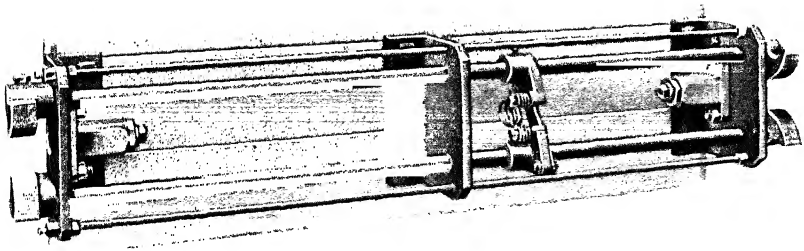


FIG. 17.—Instantaneous (serrated cam type) safety gear, fitted below car.
[*By the courtesy of Messrs. Waygood-Otis, Ltd.*]

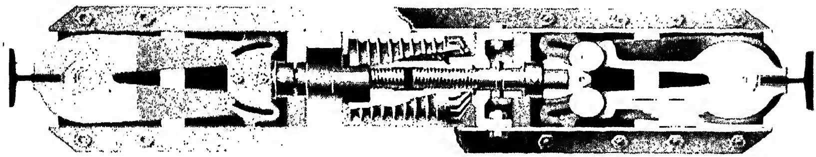


FIG. 18.—Friction type wedge operated safety gear.
[*By the courtesy of Messrs. Waygood-Otis, Ltd.*]

[*See p.* 24.

[*To face p.* 21.

guide posts and immediately brought the car to a dead stop. Safety gear is not ordinarily fitted to counterbalance weights, only to the car.

4. **Cam Type Guide Grips.**—The next important development appeared about the year 1893, and is still extensively used in Great Britain. It consists of four serrated steel cams, mounted

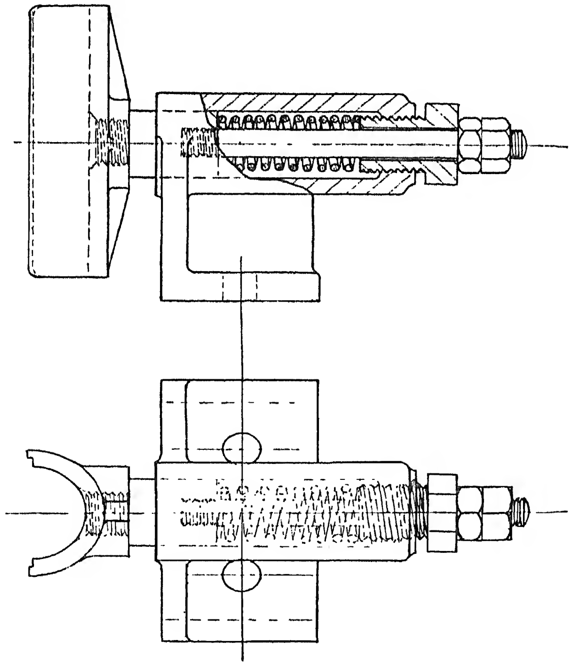


FIG. 16.—Spring-loaded guide rail shoe for round steel guide rails.
[*By the courtesy of Messrs. Marryat & Scott, Ltd.*]

on two turned steel rods, that, when the necessity arises, rotate and bring the cams into contact with the guide rails or wood backing (Fig. 17). The whole of the weight of the car and its passengers is then supported on the guides. It will be seen that this form of safety gear is practically instantaneous in action, and it is therefore only suitable for use in connection with slow-speed cars (100 ft./min.), since immediately the first contact occurs between a cam

and the guide, both steel shafts rotate and the cams are automatically applied to the guides. Further, it will only prevent the too rapid descent of the car and is useless for preventing excessive speed in the upward direction.[1]

Various makers employ different methods for operating the cams, such as slack ropes, separate safety lines between the car and the counterweight, etc., but these are largely a matter of detail. Care should be taken to see that the method employed is reliable under all conditions of operation, and is such that skilled attention is not required to maintain it, and that rust, dirt, or lack of lubrication will not render it inoperative when required.

5. Overspeed Governors.—The introduction of higher speeds called for multiple ropes, and accidents due to rope failure became, under these circumstances, very infrequent, yet car accidents continued to be recorded. Investigations indicated that runaway cars, caused by the derangement of the controlling apparatus or failure of the hoisting machinery, were the chief cause, and in the majority of cases it was found that the car speed accelerated too gradually to slacken the ropes sufficiently to operate the safety gear.

Consideration of the subject emphasised the necessity of employing safety gear that depended on velocity and not alone upon rope failure, and further that positive and quick stops were not only undesirable but actually dangerous to life and limb when effected on moderate and high-speed lifts, i.e. for car speeds of 200 ft./min. and upward.

Modern safety devices are therefore operated by an overspeed or centrifugal governor located at the top of the shaft and set for a predetermined speed, usually from 30 to 50 per cent. in excess of the designed speed of the car. If by any reason the speed of the car, when travelling in either direction, reaches that for which the governor is set, a rope connected to the safety gear, located usually below the car, is held fast, the safety gear is brought into action and the car is brought to rest. U.S.A. Regulations call for centrifugal speed governors for all lifts in which the travel exceeds 15 ft., irrespective of speed.

In practically all installations in which the safety gear is operated by an overspeed or centrifugal governor, a control switch is included in the equipment and so adjusted that it will trip, thus opening the control circuit and disconnecting the motor from the source of supply at a lower speed than the speed at which the guide grips act. This switch prevents the guide

[1] One of the objections of this type of gear is that the guides are usually badly scored when the gear comes into action.

grips from operating in the event of slight overspeeding, and it is so arranged that, unless the guide grips are in the running position, it cannot be reset.

6. Retarded Action for Safety Gear of High-speed Cars.—Mr. Thomas E. Browne, in "Passenger Elevators,"[1] states that tests have shown that a strong healthy person, when descending at speed *may* be stopped in a distance of one-fifth of the velocity height without serious injury, but that to allow for persons of ordinary physique, the stopping distance should about equal the velocity height. This figure compares with the rate of retardation of 3 ft. per sec. per sec. ordinarily employed in connection with electric tramway work and 6 ft. per sec. per sec. in emergency. Given that

H = height due to velocity (or space traversed),
V = velocity of the car (ft./sec.) at the point at which the governor operates,
g = acceleration due to gravity—say 32 ft./sec./sec.,
t = unit of time (secs.),
u = final velocity = 0.

Then

$$H = \frac{V^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$t = \frac{2H}{V + u} \quad . \quad . \quad . \quad . \quad (2)$$

Tabulating the results for the more usual car speeds the following figures are obtained :—

TABLE VI.

DATA RELATING TO THE OPERATION OF SAFETY GEAR.

Normal car speed (ft./min.)	160	240	320	400	480	560	640
50 per cent excess car speed .	240	360	480	600	720	840	960
,, ,, ,, (ft./sec.)	4	6	8	10	12	14	16
Vely. Height (H.) . (ft.)	0·250	0·562	1·00	1·56	2·25	3·05	4·00
Time (t) . . . (secs.)	0·125	0·187	0·25	0·312	0·375	0·435	0·500

Consideration of this investigation indicates that safety gear should include a resistance so designed that the car will slide a distance proportional to its velocity before stopping dead. Tests in New York on lifts rated for 600 ft. per minute have proved that a car can be brought to rest in a space of 10 ft. without serious inconvenience to the passengers.

[1] *Trans. Am. Soc. C.E.*, vol. liv., Part B, 1905.

7. Friction Type Safety Gear.—One of the common forms of friction type safety gear consists of right- and left-handed screw-threaded shafts or bolts that open the long ends of extremely strong tweezers by means of wedges, cams, or toggle joints. As the long ends are opened, the short ends close and grip the guides sufficiently tightly to hold the car (Fig. 18). Since the nut or drum in which the right- and left-hand threads are formed has to revolve a number of times before the full pressure of the tweezers is exerted on the guides, the car is brought gradually to rest without excessive shock or jerk while falling a distance of from 5 to 10 ft. according to the adjustment. Guide grips should have a minimum clearance of ⅛ in. to avoid the risk of their being brought into action accidentally and the arrangement should be such that it is unnecessary for anyone to go below the car in order to release the gear after operation.

Mr. Charles R. Pratt, in *Elevator Safeties*, has criticised this type of safety gear on the following grounds:—

(*a*) Delay of levers in getting into contact with guide rails, due to clearance (⅛ inch), which he estimates as the equivalent of from 4 to 8 ft. of car travel, during which period the speed is rapidly increasing.

(*b*) After the levers have made contact with the guide rails, if the speed is to be gradually reduced, the car must continue to travel, the drum of the gear to revolve, and the levers to bend until that distance is traversed.

(*c*) Difficulty of maintaining perfect adjustment and of taking up wear, due to faulty guide shoes.

To overcome these objections, Mr. Pratt devised an improved type, in which a spring and a latch bolt are included (Fig. 19). The operation of the governor cable first releases the latch bolt and the stored energy of a spiral spring instantly applies the pressure of the grips to the guides. As the drum continues to revolve, additional pressure is applied to the spiral spring and hence to the guide grips until finally the car is brought to rest. It will be seen therefore that the pressure on the guide grips is effected by the normal closing of a spiral helical spring and not by the bending of parts of the gear that are not springs.

Since the coefficient of friction on a greased steel guide is at times as low as 0·08, it will be evident that the jaws must grip the guides with tremendous pressure.

Specifications frequently limit the cant of the car floor, after operation, of the safety gear to ½ in. per foot of length between the guide rails, which means that the grips or cams must act practically simultaneously and with equal force.

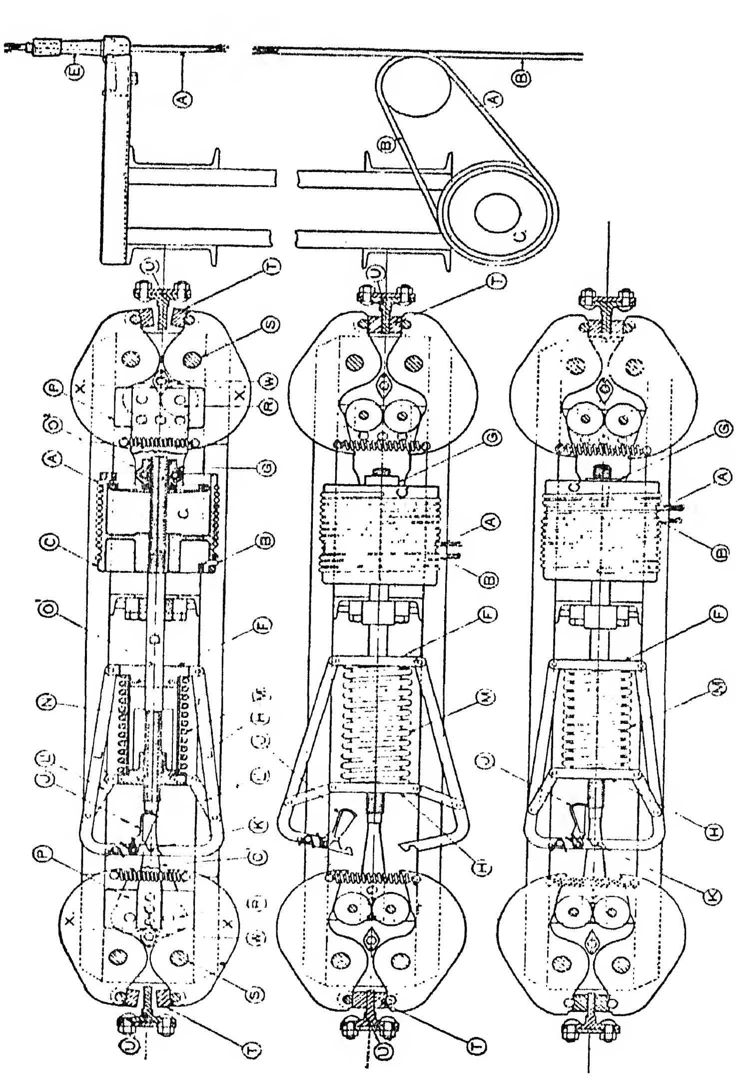


FIG. 19.—"Pratt" friction type safety gear.
[By the courtesy of the American Society of Mechanical Engineers.]

CHAPTER V.

GUIDE RAILS AND FIXINGS.

1. Wood Guide Rails.—Guide rails both for cars and counterweights have passed through several stages of development as the height of buildings has increased and higher speeds and larger cars have been demanded. The essential features of lift guides are that they shall be perfectly parallel throughout their entire length, free from risk of distortion, wear-resisting at high speeds, and dead smooth from top to bottom. In the early days solid lengths of timber were used, being either 6 ins. by 6 ins., 6 ins. by 8 ins., or 8 ins. by 10 ins., depending on the size of the installation. These timbers were dressed on all four sides and faced with maple, beech, or other hard wood. Due to trouble through cracking, twisting, and bending, this type was superseded by the sectional or compound wood post, formed by fastening together three or four 2-in. well-seasoned planks 6, 8, or 10 ins. wide. Joints between lengths of guides were lapped, and in this way a practically endless guide was obtained. The backing so formed was then faced with 2¼-in. by 2½-in. maple, beech, or other hard wood, made in short lengths and secured to it by countersunk wood screws. At one end a groove was formed and at the other a tongue, and in this manner a perfectly smooth-running rail was obtained.

English practice still favours the solid-wood guide for cheap, slow-speed, light-duty lifts, 2¼-in. square teak, mounted on a pine-wood backing, being recommended by one maker for 10 cwt. lifts up to 150 ft. per minute. Other makers retain wood only for goods lifts, using thoroughly seasoned yellow deal or Oregon pine, planed true on all sides, having scarfed joints and a section of 3¾ ins. by 3¾ ins. The same maker also retains wood guides for the counterweights, but in this case the guides are grooved, to correspond with tongues cast on the counterweights. In all cases where wood guides are used copious lubrication is essential, not only to minimise friction but to protect them from the influence of the weather.

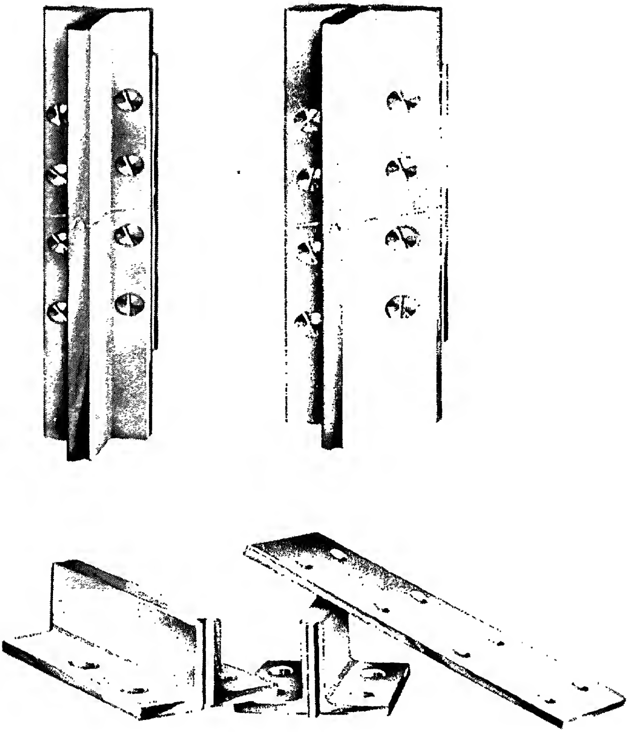


FIG. 20. Details of joints in T steel guide rails, showing tongued and grooved ends and splice-plates.

[*By the courtesy of the Express Lift Co., Ltd.*]

[*To face p.* 27.

2. Steel Guide Rails.—Immediately the demand for high speeds arose it became evident to lift engineers that for smooth and durable operation some form of steel guide which would be uniform in size, straight, and in exact alignment was essential, although some felt that the wood backing should still be retained in connection with the car safety gear. The earliest form was a cast-iron backing with a maple face, but this rapidly gave place to a "T" section steel bar in America and a round bar in this country.

TABLE VII.

DIMENSIONS OF THE GUIDE RAILS.

Lbs. per ft. run.	Width of Base (ins.).	Height of Web (ins.).	Width of Web (ins.).	Remarks.
$6\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{5}{16}$	$\frac{31}{32}$	Counter-weight
14	$4\frac{1}{2}$	$3\frac{7}{16}$	$\frac{31}{32}$	Car
21	$5\frac{1}{16}$	$3\frac{17}{32}$	$\frac{5}{8}$	
39·4	6	$5\frac{3}{16}$	1	

Guide rails, which are either cold rolled or planed steel, are usually supplied in 14 ft. to 16 ft. lengths. Alignment is secured by groove-and-tongue joints and a splice or fish-plate bolted at the back (Fig. 20). Splice-plates for car guides are frequently specified to be not less than 12 ins. long, four $\frac{5}{8}$-in. bolts being required for each end of the guide. For counterweight guides, which are not called upon to stand heavy strains from the safety gear, 9-in. plates and $\frac{1}{2}$-in. bolts are accepted. In cases where the supports on wall fixings are at a greater distance apart than 12 ft., angle iron or channel iron stiffeners are used, which run about 9 to 10 lbs. per foot.

English practice has hitherto favoured the round mild-steel guide rails, but the majority of makers are now prepared to quote for tee-guide rails, as there is less risk of the car jumping the rails.

Round steel rails are usually listed in 18 ft. lengths, the standard sizes being $1\frac{1}{2}$ in., $1\frac{3}{4}$ in., and 2 ins., although $2\frac{1}{4}$ ins. and $2\frac{1}{2}$ ins. are occasionally used for heavy duty lifts. One maker standardises 2 ins. for car guides and $1\frac{1}{2}$ in. for counterweights for all ordinary work.

The ends of the guide rails are usually of the spigot and socket screwed type, although some makers use a plain spigot and socket joint for the counterweight rails. The rails are held

in position by cast-iron palms or plates, which are screwed to them at intervals of 6 ft. (Fig. 21).

The guide rails for counterweights should be extended far enough at the top of the shaft so that when the car is at the bottom of the shaft there will be no danger of the weights coming out of the guides.

3. Guide Rail Fixings.—Details relating to guide rail fixings can be compared to the chairs and sleepers of ordinary railway practice, and in lift engineering the design adopted de-

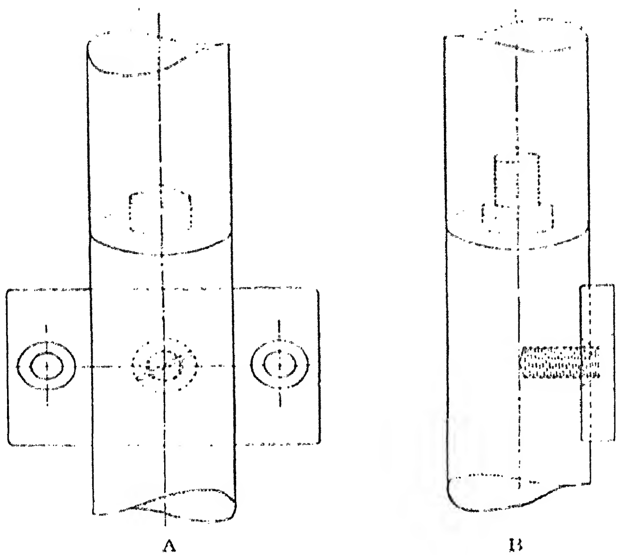


FIG. 21.—Details of joints in round steel guide rails. A, Spigot and socket plain. B, Spigot and socket screwed.
[By the courtesy of Messrs. Marryat & Scott, Ltd.]

pends rather more on the local conditions relating to shaft design and construction than on the type of rail used.

Hitherto, English practice has favoured round steel guide rails with or without wood backing; and for this type, assuming a brick shaft, wood bricks, 9 ins. by $4\frac{1}{2}$ ins. by 3 ins., cemented into the wall at vertical intervals of 6 ft., have been extensively used.

As the wood backing has been gradually dropped, due to development in the design of the safety gear, the steel guide

rails have, in certain cases, been secured direct to the wall by rag bolts, or to steel joists by means of bolts and plates (Fig. 22, A and B). Should two or more cars be run in the same shaft, a beam should be provided between each car, at the floor levels, for the support of the side guides.

To provide space for ropes, etc., between the car and the walls of the shaft, brackets are frequently found to be necessary, both for the car and also the counterweight guide rail fixings (Fig. 22, D).

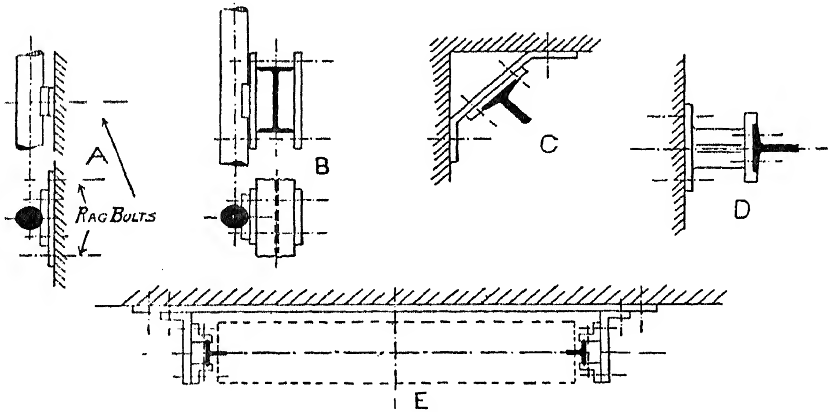


FIG. 22.—Details of steel guide rail fixings.

A, Round steel guides, with cast-iron palms, secured to wall with rag bolts. B, Round steel guides, with cast-iron palms, secured to rolled steel joists. C, Cross-corner type T steel guide rail secured to wall by wrought-iron bracket and rag bolts. D, T steel guide rails secured to wall by rag bolts, and spaced therefrom by cast-iron distance pieces. E, T steel guide rail fixings for counterbalance weight.

4. **Lubrication of Guide Rails.**—The guides of a lift should be kept well lubricated. For many years it was common practice for the attendant to climb on the top of the car and grease the guide rails by hand. This method was both dangerous and unsatisfactory and several really excellent guide lubricators have been introduced. In the "Eggler" lubricator the oil is carried from the reservoir to the guide rails by capillary attraction through three felt wicks, in exactly the same manner and just as uniformly as lamp wick carries oil to the flame. Hard fibre shoes distribute the oil.

CHAPTER VI.

BALANCE WEIGHTS.

1. Function of Balance Weights.—If a given load x has to be lifted through the distance y, then the work which will have to be done is xy, and if x is stated in units of pounds and y in units of feet the work will be xy foot-pounds. If, however, another load, equal in weight to x pounds, which may be called x', is located at a height above x of y feet, then it is said to possess potential energy of $x'y$ foot-pounds, due to its position or power to do work.

Again, if the load x be connected to x' by means of a lever having equal arms or a rope passing over a suitably placed pulley, the total work expended on raising x, provided that x' be allowed to fall freely, will be zero (neglecting friction), i.e. :—

$$\text{Given } x = x' \text{ then } xy - x'y = 0.$$

In lift work the problem of counterbalancing is not quite so simple, as the load to be lifted has one fixed and two variable factors, in addition to the friction losses of the gears, the sheaves, and the ropes. The fixed factor is the weight of the car, including the sling, the safety gear, and the guide-rail shoes; and the variable factors are the passengers and the length of rope between the overhead sheaves and the car. This latter factor varies with each position of the car in the shaft.

2. Early Designs of Balance Weights.—In the very early days the counterweight consisted simply of a length of cast iron, usually square in section, the dimensions being at least 6 ins. and the length from 4 to 8 ft. This counterbalance weight was frequently enclosed in a wooden shaft or pocket, and was located at some distance from the shaft, but, owing to the absence of guides, it scraped against the walls of the box and was noisy in operation. Frequently in lift construction, there is a space

in the shaft between the car and the walls, and designers therefore proceeded to modify the arrangements by producing flat weights which could be accommodated in these spaces. The first flat type counterbalance weights were cast solid, and on their

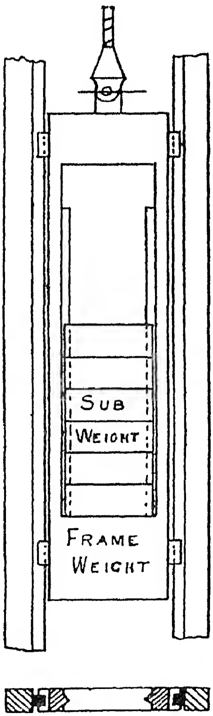


Fig. 23.—Early form of adjustable counterbalance weight. Reproduced from *Elevators* (Jallings).

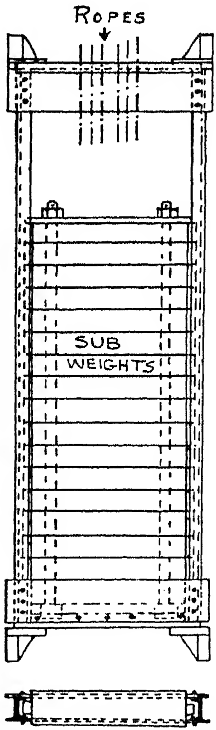


Fig. 24.—Modern American counterbalance weight. Reproduced from *Elevators* (Jallings).

longest edges tongues were provided, which were designed to run in grooves ploughed in soft pine guide rails.

Immediately electric motors were utilised for the operation of lifts, and the measurement of the power taken to start and to run the lift resolved itself, on a direct-current circuit, into one of

merely reading an ammeter, it was realised that the existing forms of solid counterbalance weight were crude and uneconomical as regards energy consumption, and the adjustable type was evolved. The early forms of adjustable counterbalance weights consisted of a hollow frame-weight of cast iron, the adjustment being made by the addition of a number of smaller weights, which were made to fit over V-shaped guides. The guide rails of soft pine were found to wear badly and maple strips were therefore added, the edges being formed to suit the new type (Fig. 23).

Due to the well-known objection to using cast iron in tension, and also to its liability to fracture should the rope break and the weight fall from a considerable height, the vertical members were replaced by wrought-iron rods, the sub-weights being grooved at the ends in order to obtain a fixing. Again, this design was found to be unsatisfactory, as in the event of the failure of the supporting ropes the rods were liable to bend when the weight fell, thus allowing the sub-weights to scatter and in themselves to become a source of danger.

3. Modern Types.—This development practically brings us to the modern form of counterweight, which almost invariably, in America, consists of top and bottom steel plates with vertical styles of steel channel, that form a groove into which the sub-weights fit. The sub-weights are securely held together by two bolts which pass through the bottom plate. This frame or sling, which is not unlike the modern car sling, is fitted with adjustable guide-rail shoes but not usually with safety gear (see Fig. 24). In England, some of the leading makers have retained cast iron for the top and bottom cross-beams and wrought-iron rods for the vertical members, but have eliminated the risk of trouble due to the rods spreading by casting holes in the sub- or pocket-weights, and threading these on to the wrought-iron rods. This arrangement provides a sound engineering job, and is, in many respects, it is thought, superior to the American design described above. The guide-rail shoes are bolted on to the upper and lower weights (Fig. 25). All counterweights should be so constructed that a piece or pieces cannot become detached should the counterweights be accidentally drawn to the top of the shaft with unusual velocity.

4. Over Counterweighting.—Many observations indicate that if an adequate number of lifts is installed, the average load in the car is 40 per cent. of the maximum load during periods of normal traffic, and specifications therefore frequently call for

counterweights to be provided, equal in weight to the dead load of the car, sling, safety gear, etc., plus 40 per cent. of the live load due to the passengers, based on a loading of 75 lbs. per square foot of car floor area. By this means maximum operating efficiency is obtained. With more than 50 per cent. over counterweight the motor will take more power to lower the empty car than to hoist the maximum load, so that the value mentioned is seldom if ever exceeded.

5. Compensating Cables or Chains. — The variable weight, due to the length of supporting rope between the overhead sheaves and the car, is relatively unimportant on short runs, but in buildings where the car travel exceeds 120 ft., it becomes a serious factor and is dealt with by connecting one or more chains between the bottom cross-beam of the counterweight and the bottom cross-beam of the car.

These chains, which are allowed to hang in a loop a little above the floor, are liable to be noisy in operation unless special precautions are observed. Alternatively, wire ropes of the same number and size as the lifting ropes, connected to the bottom of the car and to the counterweight and passing under idler sheaves in the pit may be employed for the same purpose.

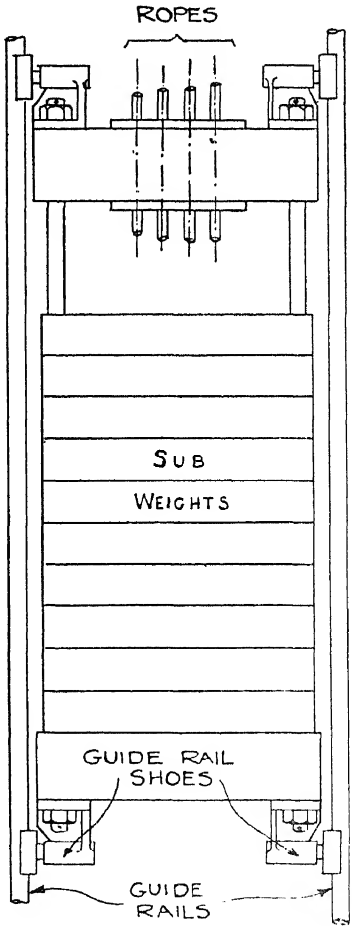


FIG. 25.—Modern English counterbalance weight. As used by Messrs. Waygood-Otis, Ltd.

CHAPTER VII.

SUSPENSION ROPES AND ROPE FASTENINGS.

1. Material for Ropes.—No detail of lift equipment gives rise to more thought on the part of lift makers and to more anxiety to inspectors than the lifting ropes. Considerable diversity of opinion exists between experts on this subject, but all are agreed that the essential requirements are durability, flexibility, and great tensile strength.

American practice favours a good Swedish or charcoal iron rope, and it is claimed that these will far outlast any of the same diameter of even the mildest steel, but English makers, with one or two exceptions, invariably put forward steel ropes. Certainly, to the layman, steel, as a material for lifting ropes, sounds much more impressive than soft iron of even the best quality, but cases exist in this country where steel ropes failed repeatedly, due possibly to excessive bending over small sheaves in awkward positions. When Swedish iron ropes were substituted they proved entirely satisfactory.

Undoubtedly lift work is particularly exacting, as sheaves and drums are frequently, of necessity, of small diameter, and the leading of heavily loaded ropes around a drum or over or around a sheave or sheaves means the constant alternate bending and straightening out of the cable, which eventually results in the well-known cracking of the wires of which the cable is composed.

When steel lift ropes are used the diameter will, for equal strength, be less than Swedish iron ropes for the same number, and this in turn permits smaller sheaves and drums to be employed. If Swedish iron ropes are used then for the same diameter and factor of safety additional ropes must be installed.

2. Rope Construction.—The question of rope construction is also a debatable one. A popular arrangement consists of six strands of nineteen wires each up to $\frac{5}{8}$-in. diameter, and six strands of twenty-four wires each for larger diameters, but several makers use a 6/12 rope. The wires composing the strands, and the strands themselves, are laid in the same direction, an arrangement known as "Lang's lay," and frequently the core of the rope

and also the core of the strands are formed of hemp cord. It is claimed for this hemp cord core that it provides a soft cushion on which the strands may rub when the rope bends during its passage over the sheaves (see Fig. 26).

Another form of rope employed by some makers consists of five strands, each strand consisting of an internal flat wire surrounded by eleven round wires, that are again surrounded by sixteen wires. The strands are, of course, oval and give a large wearing surface to the rope.

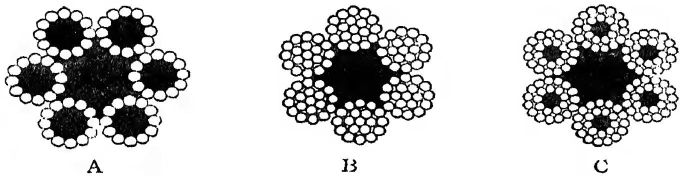


Fig. 26.—Sections of wire rope: A, 6/12 with hemp cores. B, 6/19 with hemp centre core. C, 6/24 with hemp cores.
[*By the courtesy of Messrs. Bullivant & Co., Ltd.*]

3. Selection of Ropes.—Some useful points to remember in connection with wire ropes, due to Mr. Hughes, are given below:—

(1) In general, use the lowest grade of steel (i.e. low carbon content, in order to reduce the tendency to return to the crystalline form of structure with repeated bending).

(2) In general, use a rope of medium flexibility.

(3) Use "Lang's lay" if possible.

(4) Ratio of sheave or drum to rope diameter should not be less than 26; 30 is better.

(5) If possible, employ a sheave or drum in which the ratio of diameter to rope diameter is 40, and then use a rope of low flexibility (i.e. larger size of wire).

(6) In the case of peculiar double turns, use pulleys as large as possible.

(7) Avoid unnecessary reverse bends (i.e. "S" leads).

(8) Keep the ropes well oiled. (*Note.*—The lubricant used must be one free from acid, such as vaseline, and should be applied with a brush and well worked into the body of the rope. Only the very thinnest coating of lubricant should be left on the surface to protect it from the effects of the atmosphere.)

4. Strength and Weight of Swedish Iron Ropes.—Regarding the safe working load, The Aetna Life Insurance Co.

give the figures shown in the table below for 6/19 Swedish iron.

TABLE VIII.

STRENGTH AND WEIGHT OF SWEDISH IRON ROPES.

Circum. (ins.).	Diam. (ins.).	Min. Sheave Diam. (ins.).	Breaking Stress (lbs.).	Safe Load (lbs.).	Weight per ft. (lbs.).
$1\frac{3}{16}$	$\frac{3}{8}$	18	5,000	500	0·26
$1\frac{37}{64}$	$\frac{1}{2}$	27	6,960	1,000	0·35
$1\frac{31}{32}$	$\frac{5}{8}$	42	10,260	2,500	0·66
$2\frac{23}{64}$	$\frac{3}{4}$	48	17,280	3,500	0·88
$2\frac{3}{4}$	$\frac{7}{8}$	54	23,000	5,000	1·20
$3\frac{9}{64}$	1	63	32,000	6,000	1·58

U.S.A. Government practice is to consider the safe working load as one-seventh of the breaking load, and Mr. Jallings (*Elevators*) recommends that W = 1/6 T for goods and W = 1/8 T for passenger lifts where W = safe working load and T = the ultimate strength. English engineers usually consider that the combined breaking strength of the ropes should be about twenty times the gross load supported.

5. Strength and Weight of Steel Wire Ropes.—Messrs. Bullivant & Co., Ltd., of Millwall, schedule the following data for their steel wire lift ropes (ungalvanised) :—

TABLE IX.

STRENGTH AND WEIGHT OF STEEL WIRE ROPES.

Circum. (ins.).	Diam. (ins.).	Min. Sheave Diam. (ins.).	6/12		6/19		6/24	
			Breaking Stress.	Weight per ft.	Breaking Stress.	Weight per ft.	Breaking Stress.	Weight per ft.
$1\frac{1}{2}$	$\frac{15}{32}$	28	11,400	0·25	13,400	0·36	12,800	0·33
$1\frac{3}{4}$	$\frac{9}{16}$	34	15,400	0·35	18,100	0·50	16,800	0·47
2	$\frac{5}{8}$	39	21,000	0·45	25,000	0·66	23,000	0·60
$2\frac{1}{4}$	$\frac{23}{32}$	43	26,500	0·60	31,000	0·84	28,000	0·78

6. Number of Ropes Required.—The number of ropes to be used depends upon the total load to be lifted, the minimum diameter of sheave employed, the material selected, and the factor of safety employed. With the drum type of machine it was almost universal practice to use two cables in order to keep the width of the drum face within reasonable limits, but the modern traction machine imposes no such restriction. A larger

number of cables of comparatively small diameter are used, therefore, and this is found to be very convenient, since smaller sheaves may, of course, be employed, the advantage being an additional argument in favour of the traction type machine. English makers appear, almost universally, to employ four lifting ropes for traction machines, whereas the standard American practice is six. This divergence of practice is possibly due to the fact that American lift engineers favour the Swedish iron rope, which has a lower breaking load for equal diameter, and therefore, for a given load and rope diameter, a larger number of ropes is required.

7. **Life of Ropes.**—It is difficult to give any really reliable data which will be useful as a guide to the reasonable life to be expected from lift ropes, as it depends largely on service and also on the size of sheaves and lead of the ropes. Running on a schedule, as indicated in Chapter II., for nine hours per day, under favourable conditions, a three years' life could be very reasonably anticipated, and five years in all probability. On the other hand, to the present writer's knowledge, in one case the ropes had to be replaced in nine months, and in another case they have been running for eight years and show scarcely any signs of wear.

How far a rope may be allowed to deteriorate before renewal is a question that can only be satisfactorily determined by those who are experienced in the work. They should certainly be examined at frequent intervals, and many points have to be taken into consideration, such as:—

(*a*) The amount of wear on the individual wires.

(*b*) The number of broken wires.

(*c*) The distribution of the broken wires (i.e. if distributed over the whole length or close together, thus causing local weakness).

(*d*) The extent to which corrosion is likely to have affected the interior wires.

(*e*) Excessive stretching. (The sign of an overloaded rope is excessive stretching.)

In any case, in arriving at a decision to renew immediately or to defer renewal, no consideration should be paid to the existence of the safety gear, which should be regarded purely as an appliance which will operate only if undetected flaws or weakness exist. For a thorough examination it is desirable, when possible, to take the strain off the ropes, and an endeavour should then be made slightly to untwist the strands so that a fair estimate can be made of the condition not only of the outer strands but of the inner strands also.

The strength of a rope must be judged by its weakest part, and it should be condemned when the wires, not the strands, commence cracking. Under no circumstances should a wire lift rope be spliced.

8. **Rope Fastenings.**—Several different methods are utilised, but a description of the designs commonly in use should suffice to make the subject clear.

A type adopted by one firm consists of a wrought-iron shackle, which carries two lugs. The cable is passed through the upper portion intact, the hemp core is cut out, the ends of each wire formed into a loop, and the end drawn back into the the cup of the shackle. Hot Babbit metal, which has a low

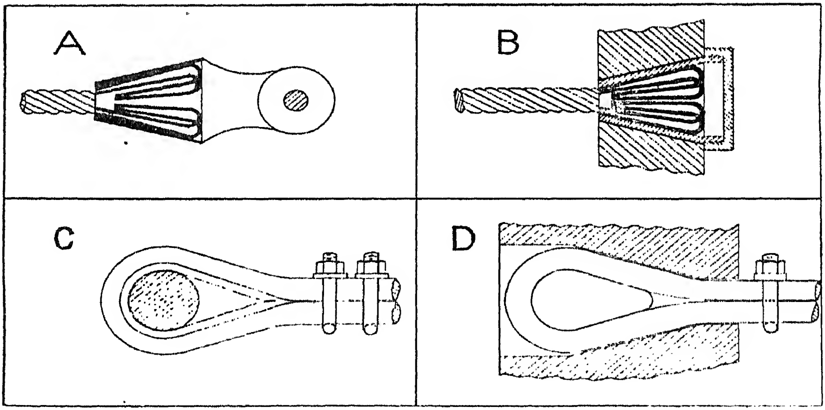


FIG. 27.—Details of rope fastenings.

melting-point, is then poured into the cup, flows into every crevice, and forms a solid bulb-shaped end which cannot, under any circumstances, pull through the bell mouth (see A, Fig. 27). Great care should be taken when running in Babbit metal to see that it is heated only slightly above the melting-point.

Another method consists of forming tapered cored slots in a casting, through which the ends of the ropes are reeved. A loose, cast-iron, pear-shaped, heart piece is slipped into the noose so formed, and the rope is then pulled up into the wedge-shaped slot. By this arrangement it will be seen that the greater the tension on the rope the tighter is the grip obtained, but should the weight be removed there is some little risk of the wedge be-

coming dislodged. To provide for this, screw clips are fitted as an additional safeguard (see D, Fig. 27).

A simple arrangement, chiefly used for car-lifting connections, consists of a steel thimble, and is shown at B, Fig. 27. This is similar to type A, but the lugs are omitted, the thimbles being held in conical holes formed in heavy cast-iron lifting plates (Fig. 15).

9. Spring-loaded Draw Bars.—On high-speed traction elevators two additional requirements have to be met.

(*a*) There is frequently a rotative movement on the part of the cable as it enters or leaves the groove of the vee sheave. This is the result of the twist or lay of the rope, and is an undesirable feature, since it has the effect of lengthening and shortening the rope as it untwists and twists, and, if not provided for, results in unequal loading of the ropes.

(*b*) High speeds and smooth acceleration and retardation are requirements which are somewhat opposed to each other, and, with solid connections between the car, the ropes and the counterweight, smooth and easy stops, free from shock and jar, would be somewhat difficult to obtain.

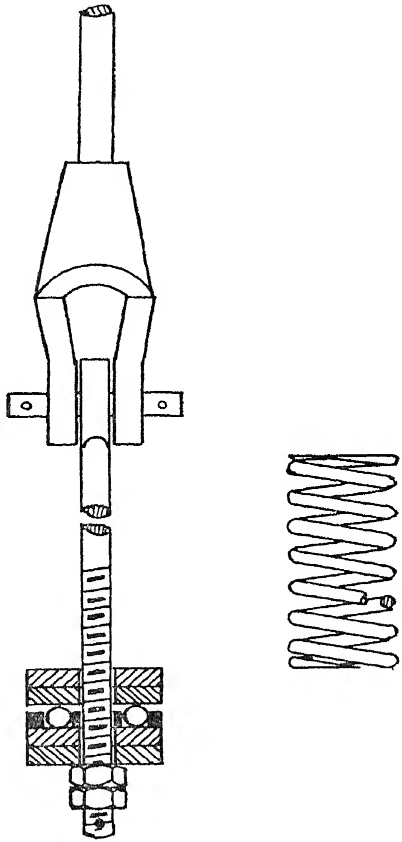


FIG. 28.—Spring-loaded draw bar fitted with ball bearings. Reproduced from *Elevators* (Jallings).

Both these requirements are provided for by the latest type of spring-loaded draw bar, which is fitted with ball bearings to permit the draw bars to revolve freely, and thereby to adjust themselves to any twist the cable may acquire, i.e. the draw bars fulfil the same functions as the buffers on a railway coach or

truck and greatly reduce the shock on starting and stopping (Fig. 28). The operation of these ball-bearing draw bars has been repeatedly observed by the writer on American lifts, and is certainly no mere talking point.

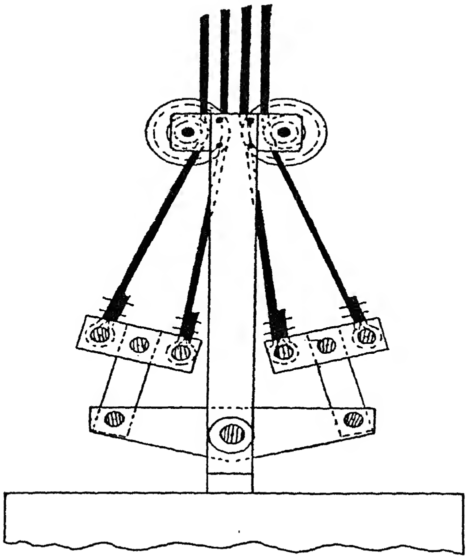


FIG. 29.—Lever type rope equaliser.
[*By the courtesy of the Express Lift Co., Ltd.*]

Another method of equalising the stress on the ropes, adopted by certain English makers, is to utilise the butterfly action of simple levers (Fig. 29).

CHAPTER VIII.

DRUM AND TRACTION OR VEE-SHEAVE DRIVES AND METHODS OF ROPING.

1. Classification of Drives.—There are two principal methods in common use for driving the ropes and hence of raising and lowering the car. They are :—

(*a*) The drum drive.
(*b*) The traction or vee-sheave drive.

In either case, the drum or the vee sheave is connected either directly or indirectly to the shaft of an electric motor, but the actual details will be discussed later in connection with gears and gearing.

2. Drum Drives.—The drum drive is the most obvious and was the earliest method employed to lift the car or platform. In this type, both car and counterweight cables are positively attached to the drum, in a manner such that while the car cables are being wound up, the counterweight cables are being unwound, and vice versa. Practically it is only possible to provide space for four ropes on the drum (i.e. two for the counterweight and two for the car), and since the minimum diameter of the drum is fixed by the diameter of the rope employed (which must be relatively large for heavy loads due to the restriction in number), the length of drum which must be employed is fixed by the total travel of the car. Obviously, therefore, drum drives are unsuitable for high buildings (ten floors is approximately the maximum) and are inconvenient in many cases for combinations of moderate travels and heavy loads, even when two ropes only are used for the car. Further, it will be noted that almost every installation calls for a special drum to meet the special requirements, and *this* enhances manufacturing costs.

Drums, which should always be supported between two bearings, are provided with two spirally cut U-shaped grooves, accurately machined for the size of rope employed and designed fully to support one-third of the rope's diameter, although the

depth is frequently restricted to $\frac{3}{16}$ in. to avoid excessive thickness of metal which would otherwise be required in the drum or barrel.

According to circumstances, the grooves start from the ends of the drum, one groove on each side (right and left-handed spirals) and lead towards one another until they meet at the centre (winding engine overhead) (Fig. 30 A). In other cases, the grooves run in pairs from one end of the drum to the other, left or right-hand spirals being employed as found most convenient (winding engine below) (Fig. 30 B). The pitch of the grooves employed for a pair of $\frac{5}{8}$-in. ropes would be $1\frac{3}{8}$ in. and for a pair of $\frac{3}{4}$-in. ropes it would be $1\frac{5}{8}$ in., thus giving a clearance of approximately $\frac{1}{16}$ in. between the different turns of cable.

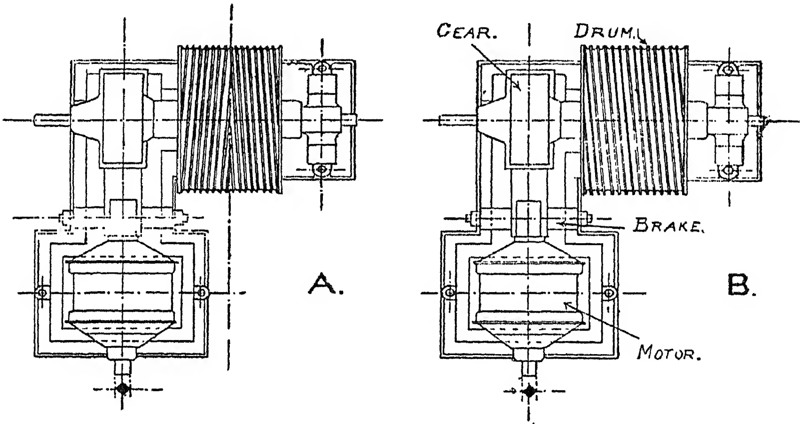


FIG. 30.—Types of winding drums: A, Grooved from flange to centre (engine overhead). B, Grooved from flange to centre (engine below).

If a leading sheave is required near the drum, as is almost invariably the case when the winding engine is located at the bottom of the shaft, it must be of the travelling or vibratory type, due to the travel of the ropes laterally along the drum. This additional complication is a further factor adversely affecting the life of the ropes, as it frequently introduces an "S" bend into the rope lead, thus shortening its life. Also, in the absence of a straight lead, side pressure and friction is produced between the drum and the sheave grooves and the ropes, with similar results.

In addition to the objections to the drum drive, enumerated above, there remain the facts that with the car and counterweights positively attached to the drum—

(*a*) Should the brake fail to hold, and the motor (due to inattention) continue to run even for a second longer than intended, there is a grave risk of the car or the counterweight being dragged through the roof of the shaft.

(*b*) When the lift is running in the downward direction, should the car, for any reason, hold up in the shaft, the engine will continue to unwind the cable, and should the obstruction or hold up be only of a temporary character, there would be considerable risk of the sudden descent of the car. To avoid an accident of this type slack cable safety devices have been designed and are installed on drums, which cut off the main supply to the motor immediately tension is removed, either from the car or the counterweight ropes. (Discussed in detail later under "Safety Devices," Chapter XV.)

3. Methods of Roping for Drum Drives.—English makers almost invariably use two sets of ropes, i.e. drum to car and

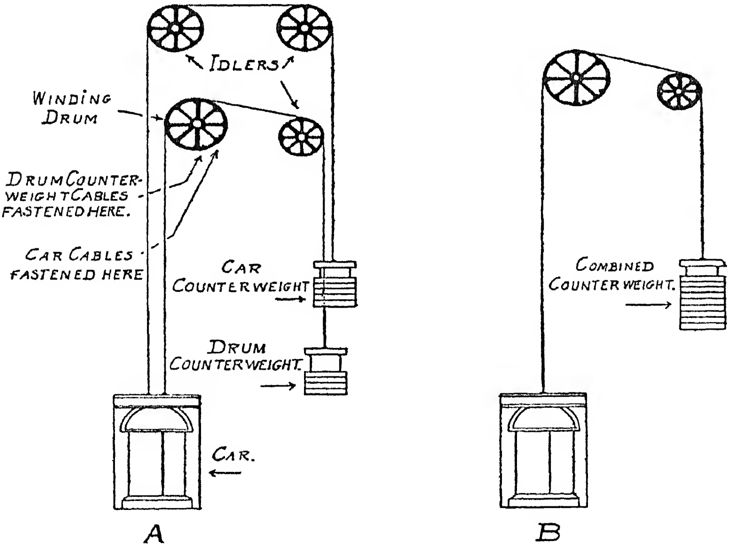


FIG. 31.—Typical roping for overhead drum type lifts: A, American. B, English.
[*By the courtesy of the American Institution of Electrical Engineers.*]

drum to counterweight—so that there is no direct connection between the car and the counterweight (Fig. 31 B). American

manufacturers, on the other hand, just as frequently, and especially for large car installations, to reduce the load on the drum and drum bearings, use three sets of ropes, i.e. drum to car, drum to counterweight, and car to counterweight direct, two sets of counterweights being used. The counterweight which is connected direct to the drum, termed the drum counterweight, is designed to offset a certain percentage of the passenger load, usually 40 per cent. of the car capacity, and the other (termed the car counterweight) is designed to counterbalance the dead load — car, sling, safety gear, etc. (Fig. 31 A). There should be at least two turns of rope round the drum at each limit of travel both for the car and for the counterweight.

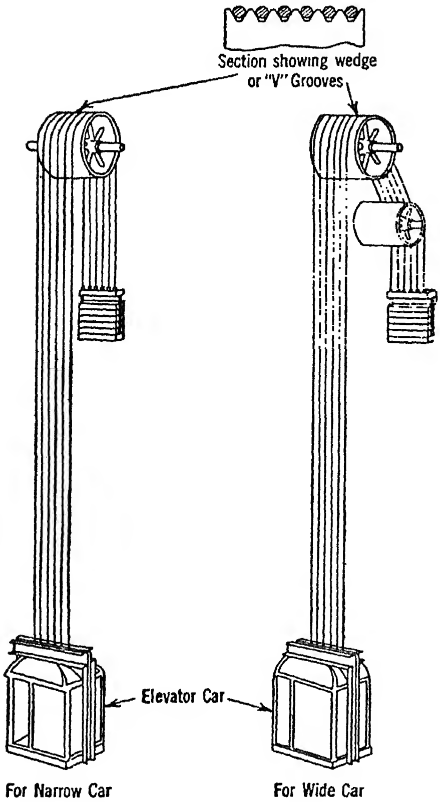


FIG. 32.—Typical roping for overhead half-wrap traction or Vee-sheave lifts.
[*By the courtesy of the American Association of Electrical Engineers.*]

4. **Traction or Vee-Sheave Drive.**—Due to the objections mentioned in connection with drum drives, a new method of driving the ropes was evolved, termed the vee-sheave, or traction drive. In its simple form the wide-faced drum is replaced by a sheave, not more than 12 ins. in width across the face, provided with from four to twelve grooves, which are no longer spiral and U-shaped, but are separate and V-shaped, and drive the ropes, which are not permitted to bed on the bottom, by means of the frictional contact between the upper faces of the groove and the rope—hence the name *traction drive*. By this arrangement and

without any modification to the winding engine any length of car travel can be obtained.

With this type of drive the risk of overwinding practically disappears, since either the car or the counterweight eventually lands upon the buffers and—the tension on the ropes being reduced—the driving sheave can continue to revolve without anything serious happening. Similarly, should the descending car be held up in the shaft for any reason, the tension on the ropes will be reduced and the slack rope safety device, fitted to all drum drives, is, therefore, unnecessary (Fig. 32).

The only real objection that can be advanced against the traction drive, apart from groove wear, is rope slip in connection with large cars, due to inaccurate counterbalancing, or excessively rapid acceleration or retardation, or the excessive use of oil on ropes.

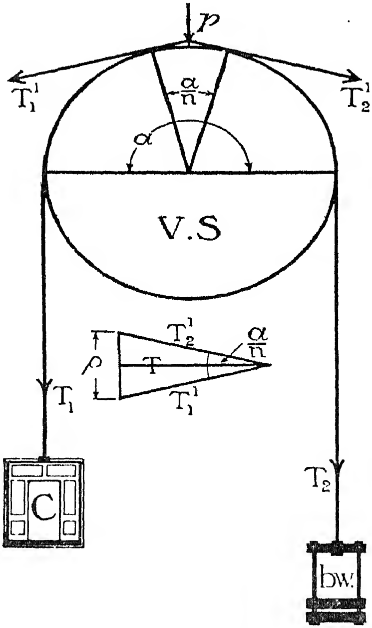


FIG. 33.—Rope slip on Vee-sheave or half-wrap traction machines.

5. Rope Slip on Traction Drives.—The relation between the car, the counterweight and that portion of the vee sheave embraced by the ropes (termed the angle of lap) necessary to prevent the ropes slipping in the vee grooves is similar in many respects to the theory of belt drives.

Consider the vee sheave, v.s., in Fig. 33 to be stationary, and the car and the balance weight to be attached to the ropes. The car C produces a tension in the ropes T_1; in order to raise the car, the balance weight, b.w., must produce a tension T_2 greater than T_1 by the amount of friction between the rope and the vee sheave.

Let F = frictional resistance of the ropes,
p = normal pressure between the ropes and the sheave at any point.

Then, if μ = coefficient of friction,

$$F = T_2 - T_1 = \Sigma \mu p.$$

Let the angle a embraced by the ropes be divided into a great number of equal parts, say n parts, so that $\frac{a}{n}$ is very small; then the tension on both sides of this very small angle is nearly the same. Let the mean tension be T; then expressing a in circular measure we have

$$p = T\frac{a}{n}.$$

The friction at any point is (neglecting rope stiffness)

$$\mu p = \mu T\frac{a}{n} = T'_2 - T'_1.$$

Writing $\frac{a}{n}$ as δa; also $T'_2 - T'_1$ as δT. Then

$$\mu T \,.\, da = \delta T$$

which in the limit becomes

$$\mu T \,.\, da = dT$$

$$\frac{dT}{T} = \mu \,.\, da.$$

Summarising these small tensions, expressed in terms of the angle of lap:—

$$\int_{T_1}^{T_2} \frac{dT}{T} = \mu \int_0^a d_0$$

$$\log_e T_2 - \log_e T_1 = \mu a$$

$$\log_e \frac{T_2}{T_1} = \mu a$$

$$\frac{T_2}{T_1} = e^{\mu a}$$

where e is the base of the Naperian logarithms = 2·718. This is the relation giving the maximum ratio permissible between the car and the balance weight for the ropes not to slip over the vee sheave.

For convenience, the problem has been investigated as for a belt on a flat-faced pulley. Since the rope does not bottom in a

vee groove, but wedges itself in (Fig. 34), the normal pressure is thereby increased to

$$P^1 = \frac{P}{\sin\frac{\theta}{2}}.$$

If the angle is 45°, $P_1 = 2{\cdot}6P$, and the most convenient method of dealing with this increased pressure is to use a false coefficient 2·6 times its true value (vide *Mechanics Applied to Engineering*, Goodman).

Assuming the coefficient of friction μ of a wire rope or cast iron to be 0·192, the false μ becomes $0{\cdot}192 \times 2{\cdot}6 = 0{\cdot}50$, and for oiled rope $0{\cdot}135 \times 2{\cdot}6 = 0{\cdot}35$. The value of the limiting ratio of car to balance weight or vice versa for various angles of lap and for the two values of μ for a 45° groove are given below.

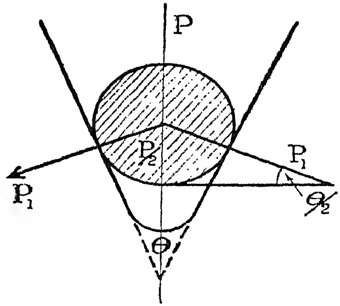


FIG. 34.—Increase of coefficient of friction due to Vee-groove.

TABLE X.[1]

LIMITING RATIO OF CAR TO COUNTERWEIGHT.

μ.		Angles of Lap (degrees).						
Actual.	False.	120	130	140	150	160	170	180
0·192	0·50	2·84	3·10	3·38	3·70	4·04	4·41	4·81
0·135	0·35	2·08	2·21	2·37	2·50	2·66	2·83	3·00

[1] *Belts for Power Transmission*, Dunkley.

6. Full-wrap Traction or Cross-over Drive.—Previously the "half-wrap" traction, i.e. an arc of contact of 180° or less, depending on the depth of the car, between the sheave and the rope, has been described; but, in certain cases, it is desirable to arrange for a "full-wrap," or "cross-over" drive. This actually consists of two half wraps, or a total arc of contact of approximately 360°, between the rope and the sheave. The full wrap is obtained by adding an idler sheave (i.e. a sheave which is not connected to the motor), fixed either above or below the main sheave, depending on the position of the

engine, and having its axis set at a slight angle to the main shaft, so that the ropes are led off the first set of grooves on the driving sheave to the grooves on the idler sheave and back to the main sheave, i.e. twice round the main sheave and once round the idler. Frequently, before leading into the shaft,

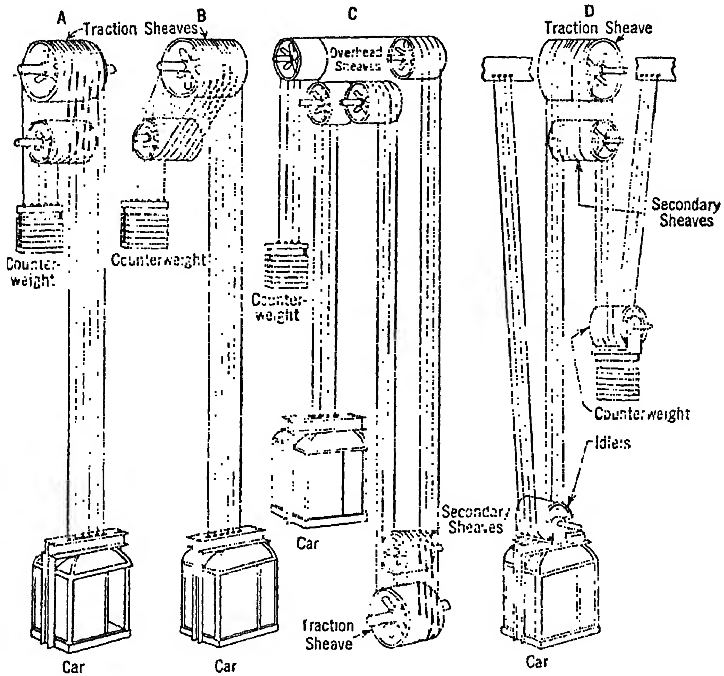


FIG. 35.—Typical roping for full-wrap traction or cross-over drive lifts.
[*By the courtesy of the American Institution of Electrical Engineers.*]

A, Engine above, roped one-to-one.
B, Ditto, with idler set off for deep car.
C, Engine below, roped one-to-one.
D, Engine above, roped two-to-one.

the ropes are deflected by the idler, in order to lead them plumb over the car, or over the counterbalance weight, or into the shaft, as the case may be (Figs. 35 A, B, C, and D). In full-wrap traction or cross-over drives, some makers adhere to the V-shaped grooves, but the majority prefer the parallel side U-groove, and claim that it is possible to place a load in the

car equal to twice that of the counterweight without the ropes slipping over the driving sheave. One possible objection to this type of drive is that the driving sheave is required to take double load, due to the double wrap necessary in this design which results in reduced efficiency.

7. **Gearless Two-to-one Roping.**—In certain instances, gearless winding engines are used, i.e. the driving sheave is mounted directly on the motor shaft. Obviously, this involves an excessively slow speed and correspondingly expensive motor of large size. If the system of roping shown in Fig. 35 D, termed "two-to-one" (as opposed to one-to-one roping shown in Figs. 35 A, B, and C), is utilised it is possible to install a higher speed, cheaper, smaller, and lighter motor. This type is used for large cars and speeds between 400 and 500 ft. per minute. It is smooth and quiet in operation, and has recently been designed in the half-wrap or vee-sheave form, which has the effect of reducing the number of rope bends from ten to six, thereby extending the useful life of the rope.

CHAPTER IX.

GEARLESS AND GEARED WINDING ENGINES AND LOCATION OF ENGINE.

1. Component Parts of Winding Engine.—The winding engine consists of the drum or vee sheave, the gearing (if any), the motor, and the brake, all mounted upon a common bed-plate, formed of cast-iron or rolled steel joists. Briefly stated as above, the proposition, superficially considered, appears to be an extremely simple one, but actually in practice it is complicated, due to the numerous and special requirements that must be met in order to obtain the permanently reliable, silent, rapid and vibrationless machine, which the present-day purchasers, with every reason, demand.

2. Efficiency of Winding Engines.—In lift installations in which the car floor area is relatively large, the number of passengers carried may vary between the extreme limits, but the weight in the counterbalance cannot, as a rule, be varied. Under these conditions it will be observed the car load may either (*a*) considerably exceed, (*b*) be equal to, or (*c*) be considerably less than the balance weight, and therefore, in the absence of special precautions, the car could, under certain circumstances, raise the balance weight or vice versa, without assistance from the motor. Should it be desired to prevent the possibility of this happening, friction may intentionally be introduced into the transmission system, thereby lowering the efficiency of the machine, and increasing the cost of operation but, at the same time, considerably increasing the safety factor.

Let: (*a*) The work supplied to a machine be equivalent to lowering a weight W, through a height h.

(*b*) The useful work done by the machine be equivalent to raising a weight W_u through a height h_u.

(*c*) The work done in overcoming friction be equivalent to raising a weight W_f through a height h_f.

(*d*) η be the mechanical efficiency.

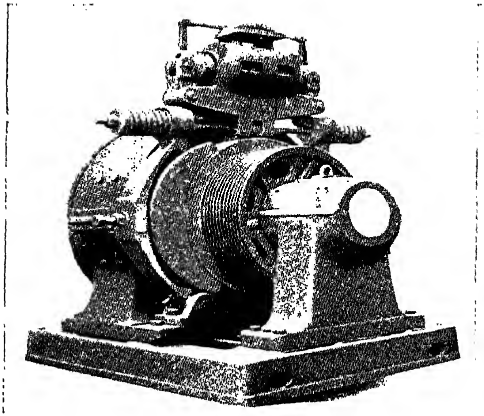


FIG. 36.—Gearless traction type lift engine.
[*By the courtesy of Messrs. Kaestner & Hecht.*]

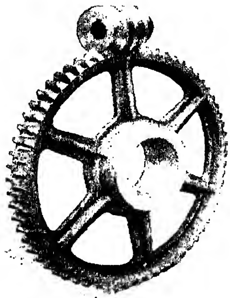


FIG. 38.—Worm and wheel of single worm gear.
[*By the courtesy of the Northern Manufacturing Co., Ltd.*]

[*See p.* 55.

[*To face p.* 51.

Then $$\eta = \frac{\text{the work got out}}{\text{the work put in}} = \frac{W_u h_u}{W_u h_u + W_f h_f}.$$

Now if the frictional resistance is to support the unbalanced load in the car or the counterweight the minimum frictional resistance is obviously when

$$W_f h_f = W_u h_u.$$

Substituting this value in the expression obtained above, we get—

$$\eta = \frac{W_u h_u}{W_u h_u + W_u h} = \frac{W_u h_u}{2W_u h_u} = \frac{1}{2}.$$

Thus in order that a winding engine may be self-sustaining its efficiency cannot be greater than one-half, or 50 per cent. (See *Mechanics Applied to Engineering*, Goodman.)

The "line to load" efficiency varies from 45 to 75 per cent., depending upon the size and design of motors, engines, and roping.

3. Classification of Winding Engines.—Hitherto winding engines have commonly been classified according to the type of drive adopted, i.e. drum, vee sheave, or half-wrap traction, and cross-over or full-wrap traction. This method sufficed until modern developments demanded a departure from the standard type of gear then used, but with the introduction of new methods a new classification was necessary, and the type of transmission gearing was considered to be a more suitable basis.

Winding engines may either be built gearless (which is the latest development for modern high speed, long travel machines) or with the under-mentioned types of gear :—

(*a*) Single worm and gear.
(*b*) Single herring-bone gear.
(*c*) Tandem worm and gear.
(*d*) Single worm and gear with external spur back gearing.
(*e*) Single worm and gear with internal spur back gearing.
(*f*) Car levelling single worm and gear.

4. Gearless Traction.—In the gearless type, which is suitable only for traction drives, the vee sheave is mounted directly on and keyed to an extension of the motor shaft, so that it will be seen that the motor armature or rotor requires to make one revolution for each revolution of the vee sheave (Fig. 36). The sheave, therefore, must be of large diameter in order to ensure

a reasonable life for the ropes, and this condition calls for an abnormally slow speed motor, which is, comparatively speaking, larger, heavier, and more expensive than the standard range of lift motor running at 600 to 1000 revolutions per minute. In the discussion on Suspension Ropes it was stated that, for long life, the sheave should be at least forty times the diameter of the rope, and, assuming a $\frac{5}{8}$-in. diameter rope, the minimum sheave diameter would be 25 ins. The speed of the motor, in revolutions per minute, for various car speeds, with one-to-one and with two-to-one roping, would, under these circumstances, be as follows:—

TABLE XI.

MOTOR SPEEDS FOR GEARLESS WINDING ENGINES (25-in. Sheave).

Car speed, ft. min.	350	450	550	650
Motor r.p.m., roped:				
(*a*) One-to-one	54	69	85	100
(*b*) Two-to-one	108	138	170	200

Generally speaking, the increased cost of the slow-speed motor will be found more than to balance the saving on the first cost of the gear, but the operating cost of the gearless type is much lower than any of the geared type of engines, as the reduced efficiency of the motor, due to the lower speed, is almost insignificant as compared with the gain in efficiency obtained by eliminating the gear.

TABLE XII.

RELATIVE PRICES, EFFICIENCY FIGURES, AND WEIGHTS FOR A DIRECT-CURRENT 25 H.P. MOTOR AT DIFFERENT SPEEDS.

Speed, r.p.m.	1150	760	520	270	230	190
Price	124	150	174	254	306	330
Efficiency, per cent.	90·0	88·5	88·0	87·0	85·5	85·0
Weight, lbs.	1484	1850	2800	4216	5866	6970

Due to the limitations of motor speed, car speeds with the gearless engine roped one-to-one lie between 400 and 700 ft. per min. and may not, therefore, be expected to be extensively used in England in the very near future. It is a very smooth and quiet machine in operation, and gives a high full-speed

operating efficiency over long travels. Two-to-one roping permits of the motor running at twice the speed for the same car speed—usually 400 to 500 ft. per min. This machine has until recently been built in the U-groove, full-wrap traction or cross-over drive type, giving ten rope bends and a lower full-speed efficiency. Recently, however, a half-wrap or ordinary vee-sheave machine, also roped two-to-one, has been built, thus reducing the number of rope bends to six, which is equal to one-to-one roping, and the efficiency will probably be similar.

Possibly, to some of the older lift engineers, the gearless machine, *which is not self-sustaining*, may appear to be an invention not to be encouraged, but as the type is extensively used in America, and as taller buildings for London are under discussion, it was thought to be very desirable to include a description of it. Nelson S. Thompson, Chief Electrical and Mechanical Engineer in the Supervising Architect's Department of the U.S.A. Treasury Department, writing in *Mechanical Equipment of Federal Buildings*, says: "The gearless traction type of machine, which is the latest and most satisfactory production of the elevator industry, is recommended for use in all cases where the speed loads vary between 1600 and 3500 lbs., and where the speed is to be 400 ft. per min. or over."

5. **"Fraser" Duplex Motor.**—Another form of the gearless type of traction lift is the "Fraser" duplex continuous running motor briefly referred to in Chapter I. and described by Mr. T. E. Browne (*Trans. Am. Soc. Civ. Engrs.* 1904) as follows:—

"This machine consists of two motors, superimposed, each carrying a grooved pulley on its armature shaft, driving a set of endless cables.

"The car is suspended by wire cables attached to a weighted sliding frame carrying a sheave, over which the endless driving cables pass. A counterweight is suspended by wire cables to a second travelling frame similar to that for the car, over the sheave of which the other bight of the endless cables passes. In a modified form, both bights of endless cables run on sheaves in the same frame, tension on the endless cables being maintained by a tension sheave and weight.

"It will be evident by an inspection of the diagram (Fig. 37) that if both motors are moving at the same speed, and in opposite directions, the driving cables will run without moving the car or counterbalance; thus when both motors are moving at the same speed, the car and the counterweights stand still. In order to overcome any very slight variation of the speed of the motors,

tending to cause the car to crawl, a magnet brake is applied to the overhead sheave. If one motor is slowed down, and the

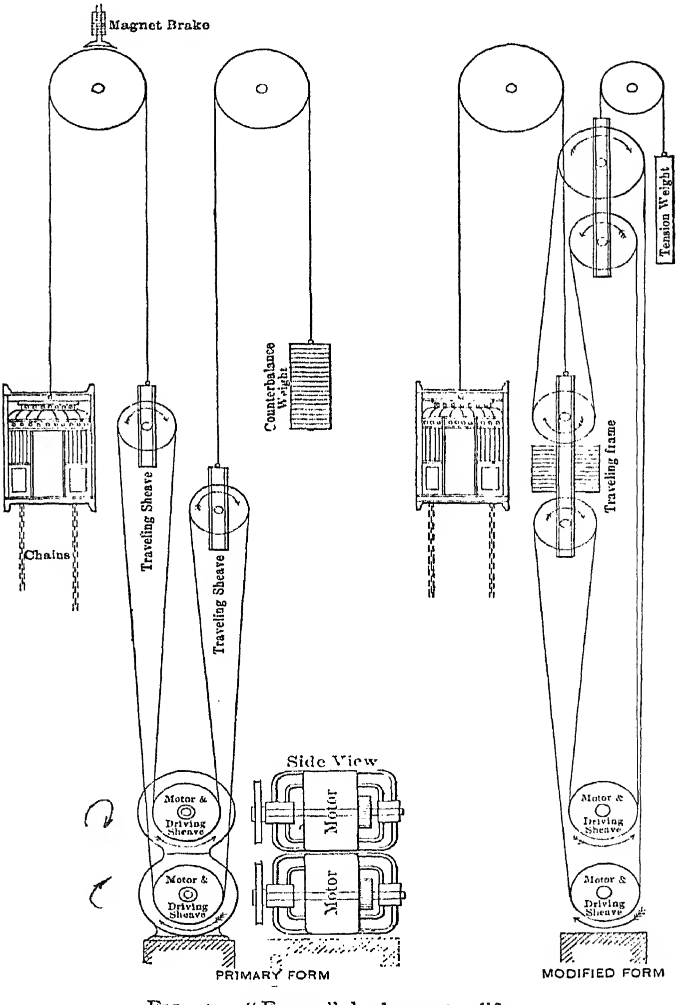


FIG. 37.—"Fraser" duplex motor lift.
[*By the courtesy of the American Society o Civil Engineers.*]

other motor speeded up, the driving rope will run faster over the pulley of the fast motor and more slowly over the pulley of the slow motor, and the difference is made up by motion of the sliding frames, which in turn impart their motion to the car and counterweight. The speed of the car, therefore, will be half the difference of the circumferential speeds of the driving pulleys.

"The motors run normally at 400 rev., and can be speeded and slowed down to 520 and 280 rev. respectively, thus giving a range of speed of the car from zero to 600 ft. per min., with driving pulleys 19 ins. in diameter.

"The motors are shunt-wound, and are controlled by varying the shunt fields. The operator governs the speed by moving a rheostat in the car, which reduces the resistance in the field of one motor and increases it in the field of the other.

"In the handling, this type of elevator excels any other yet produced. It can be reversed from full speed in one direction to full speed in the other, retarding, stopping, and accelerating in the opposite direction without shock or jar; and on account of its rapid acceleration and positive stop, can maintain a very high average speed between landings.

"It was claimed for the Fraser type of elevator that, as the motors were continuous-running, a great saving of operating current would result. as a large proportion of the current consumed by the drum machine is used in stopping and starting. Tests of these machines in actual operation do not substantiate these claims, as the actual current consumption is greater than that of a drum machine carrying the same load. It is claimed, however, that this is more than compensated for by the superior service. On account of the small diameter of the driving sheaves, ordinary wire cables wear rapidly and compound cables are used. These consist of a steel-wire core surrounded by manilla or hemp, thus combining tensile strength with flexibility."

So far as the author is aware there are no lifts of this type installed in England.

6. Single Worm and Gear.—Due to the relatively high degree of efficiency obtainable, to the fact that its dependability has been completely proved, and to the important characteristic of safety, the single worm and gear is and has been, almost since electric lifts were first built, the most popular method of transmitting power from the comparatively cheap, high-speed motor (600 to 1000 r.p.m.) to the slow-speed drum or vee-sheave shaft (20 to 40 r.p.m.) (Fig. 38).

Combined with the vee sheave or traction drive (half or full

wrap) it is, in common with the tandem worm and gear (described later), the safest form of winding engine, for, although the worm and wheel unit permit motion to be transmitted from the motor to the rope, it is impossible, due to the design, for the rope to transmit motion to the motor—hence its name "*Self-sustaining gear.*"

In the early forms, the worms were made of Swedish wrought iron, by welding bands or rings around a piece of shafting at the point where the worm threads were to be formed, the threads afterwards being turned in a lathe, and the gear wheels, to mesh with these worms, were made of cast iron with cast-iron teeth set at an angle across the face. Later developments produced cast-steel worms with an improved angle of thread, bronze gear wheels, used with a forged steel worm, and also bronze worms with bronze gear wheels.

Modern gears consist of a high tensile steel worm forged solid with the shaft, the teeth of the worm being accurately cut out of the solid, on modern worm milling machines, case hardened on the threads, and afterwards ground to pitch and highly polished. The construction of the gear wheel (with which the worm meshes) is again a debatable subject, but commonly consists of a phosphor bronze rim shrunk the full width of the wheel on to an accurately machined cast-iron centre, and pinned with set screws. Alternatively some makers prefer a phosphor bronze rim, mounted (not shrunk) on and securely fastened to a cast-iron centre with fitted bolts; but one maker, at least, uses cast iron both for the centre and for the teeth.

There is a very marked divergence of opinion regarding the relative position of the worm and the wheel, some makers preferring to place the worm above the wheel, and others, the majority it is thought, to place it below (Fig. 39). Briefly summarised, the advantages of placing the worm above the wheel are: Facility for inspection of the worm without draining off the oil; the location of all shafts above the oil level, thus reducing the risk of oil leakage; mechanically good design, as the weight and hence the centre of gravity of the engine are low down (Fig. 40). A disadvantage of this arrangement is that wear in the bearings of the vee-sheave shaft tends to increase the distance between the worm and wheel. Conversely, the advantages of locating the worm below the wheel are: Perfect lubrication, since the teeth of the worm and wheel in contact are immersed under a good head of oil; facility for inspection of the gear wheel; convenient disposal of the brake gear; and the outer bearing of the vee sheave is carried on the engine bed-plate, thus securing perfect alignment at all times (Fig. 41).

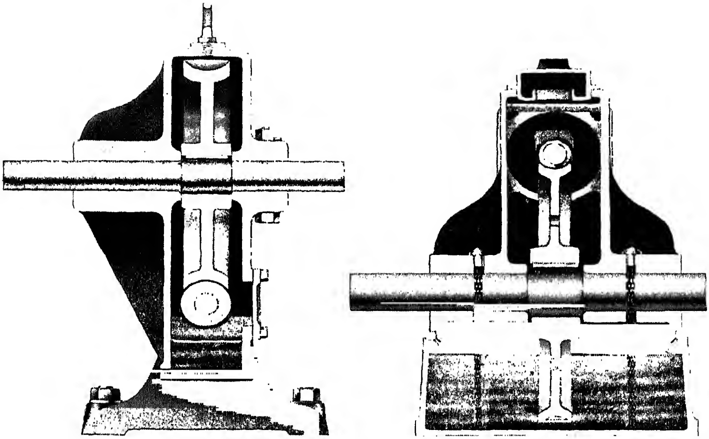


FIG. 39.—Position of worm and wheel: Left, worm below; Right, worm above.
[By the courtesy of Messrs. Major, Smith & Stephens, Ltd.]

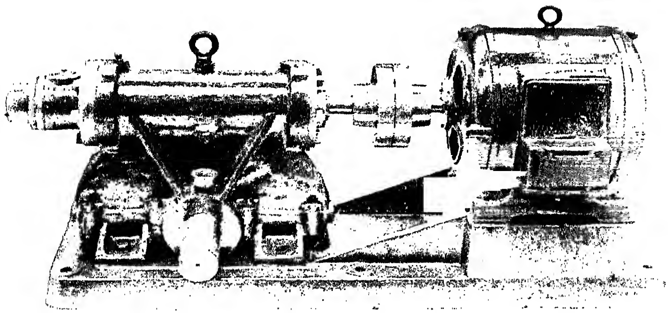


FIG. 40.—Winding engine with worm above wheel.
[By the courtesy of the Northern Manufacturing Co., Ltd.]

[*To face p.* 56.

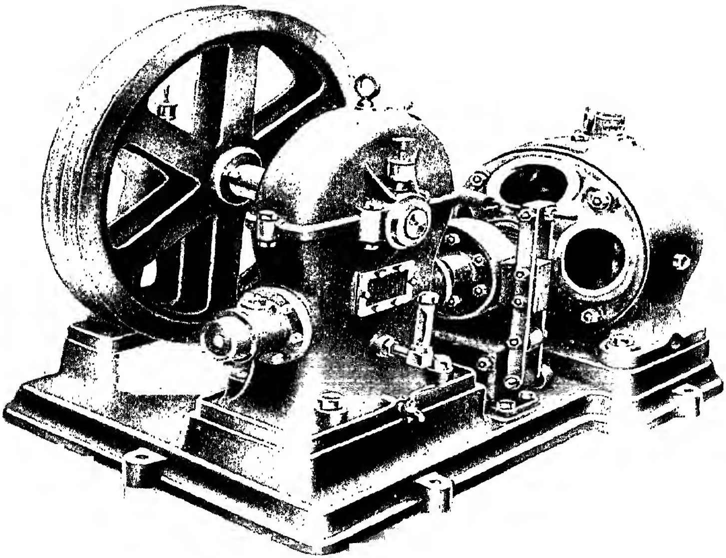


FIG. 41.—Winding engine with worm below wheel.
[*By the courtesy of the Northern Manufacturing Co., Ltd.*]

[*See p. 56*

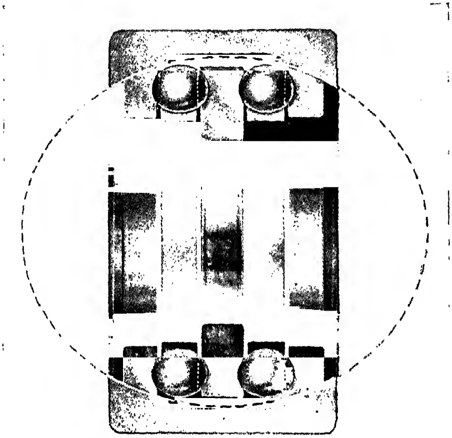


FIG. 42.—Double acting thrust bearing for worm shaft.
[By the courtesy of Messrs. Kaestner & Hecht.]

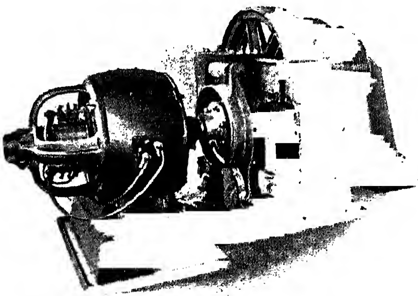


FIG. 44. FIG. 45.

FIG. 44.—Herring-bone, or double helical, gear.
[By the courtesy of the Northern Manufacturing Co., Ltd.]

FIG. 45.—Herring-bone gear lift engine (upper part of case removed).
[By the courtesy of Messrs. Kaestner & Hecht.]

[*See p.* 59.

[*To face p.* 57.

With either arrangement of the worm and wheel the lifting capacity obviously depends upon the resistance offered by the worm shaft bearings to the end thrust produced on the worm shaft immediately motion is attemped either by the worm or the wheel. In lift work the direction of the end thrust may be either way, and is taken care of by double thrust bearings of either the standard alternating steel and bronze ring type running in oil, or by means of specially designed ball bearings (Fig. 42).

The important part played by these thrust bearings in the successful operation of modern electric lifts, equipped with the single worm and gear type of engine, can be shown by the following simple example: Assume a 30-in. drum lifting a 2000 lbs. load with a 24-in. diameter gear wheel. Under these circumstances the end thrust will be

$$\frac{2000 \times 30}{24} = 2500 \text{ lbs.}$$

The casing for the worm and gear wheel, which is of cast iron, is usually of an extremely solid design and construction, as it almost invariably carries at least one, and occasionally two, of the bearings of the wheel shaft. The design most frequently adopted is to form it in halves, with accurately machined, oil-tight, horizontal joints and fitted bolts, an inspection cap being provided in the upper half. The lower half forms the oil bath for the gear, and when the worm is located below the wheel, a stuffing box is provided for the worm shaft to prevent the escape of oil from the case (Fig. 41).

Probably a dozen gear case sizes will enable any lift manufacturer to meet, from stock, the conditions of load and speed ordinarily specified, but in order to utilise standard motor frames and speeds three or four gear ratios are necessary for each frame size, due to the restrictions on sheave diameter imposed by the ropes (Fig. 43).

In lift work, when safety is of prime importance, a high reversed efficiency of the gear is undesirable, i.e. in order to lower the car it should be necessary to apply an additional force acting in the same sense as the load, to ensure that it shall be self-sustaining, or, in other words, the car will not run down should the current to the motor fail, and the brakes, due to lack of adjustment, fail to act.

For many years a worm pitch of 10° to 12° was considered good practice, but investigations and experience have proved that for lift service 15° to 20° is more satisfactory.

The allowable pressure at the pitch line of a worm and wheel does not, as a rule, exceed 2500 lbs. with the worm running in oil. Higher pressures may be used but undue heating, wear, and cutting will in all probability occur.

The field of application of the single worm and gear is extremely wide, since it is regularly used for car speeds from 50 to 450 ft. per min., and up to 300 to 400 ft. per min. for speed

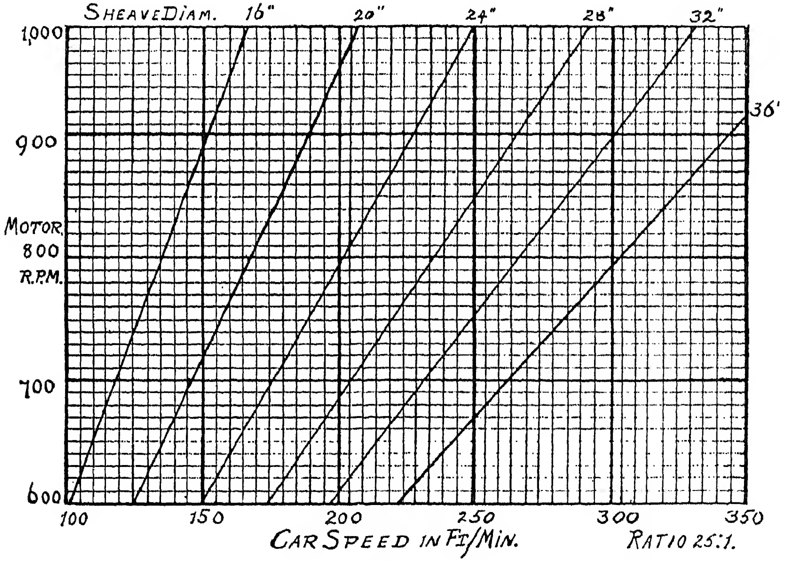


FIG. 43.—Graph connecting motor speed, diameter of driving sheave, and car speed, for a given gear ratio.

[*Example.*—If a car speed of 200 ft. per minute is required, and a 700 r.p.m. motor is to be used, note the point on the horizontal base line marked 200, and ascend vertically to the point of intersection with the horizontal line marked 700, which is the motor speed. The nearest diagonal line to this point is marked 28 ins. on the upper margin, which means that a sheave diameter of 28 ins. for a gear having a ratio of 25 to 1 will be required, the actual car speed being 205 ft. per minute.]

loads from 1600 to 4500 lbs. it is regarded as a standard. A comparison of operation records for the single worm and gear engine with the gearless engine will usually indicate that the former shows to advantage on locals, i.e. for cars stopping at very frequent intervals, although it has a lower full-speed operating efficiency. Another valuable feature of this type is due to the fact that, within limits, the vee sheave can be made half the

depth of the car, thus avoiding the use of idlers and increasing the cable life, when the engine can be located overhead. Gear wear, on engines supplied by a first-class maker, is infinitesimal provided lubrication is attended to and the right quality of oil (preferably high grade castor) is employed.

7. **Herring-bone or Double Helical Gear.**—To meet the demand for car speeds higher than could be successfully handled by the single worm and gear, at prices lower than could be quoted for gearless engines, the herring-bone, or double helical, gear, which had been used for motor speed reduction in connection with pumping plants, rolling mills, and turbine engines with extremely satisfactory results, was introduced for lift service some years ago (Fig. 44).

Briefly described, it consists of the usual cast-iron bed-plate with gear case, drum or vee-sheave bearings, and motor (500 r.p.m.) mounted upon it, but instead of the worm and gear a bronze spur gear and pinion are used to drive the drum or vee-sheave shaft. The speed ratio between motor and vee shaft is about 5 or 7 to 1, and the teeth are generally cut at an angle of about 60° with the side of the wheel, or 120° between the reverse position of the tooth. This is adopted in order to counteract the lateral stress on the wheel—hence the name *herring-bone* (Fig. 45).

The chief advantages of the herring-bone gear drive are—

(*a*) Smooth running qualities.
(*b*) Complete absence of vibration.
(*c*) Absorption of end thrust.
(*d*) Freedom from wear.
(*e*) Remarkably high efficiency.
(*f*) Utilises a medium speed and relatively cheap motor.

Due to the fact that the efficiency is high the herring-bone, in common with all types of spur gearing, is liable to race when lowering a heavy load, or when raising an empty car. To meet this risk, a centrifugal governor may be fitted which is directly connected to the pinion shaft, and is arranged to apply a brake whenever the scheduled speed is exceeded.

8. **Tandem Worm and Gear.**—Specifications for heavy duty (2000 to 4500 lbs.) moderate speed (175 to 400 ft. per min.) lifts are not infrequently met by the offer of tandem worm-geared engines in which intermeshing right and left-hand gears are employed in place of the single worm and gear previously described. By this means double the load can be carried for the same limiting pressure at the pitch line of the worm and wheel.

The manner in which the double gears intermesh produces, moreover, a three-point contact, which permits the gear itself to compensate for any end thrust of the worm shaft and eliminates the necessity for end thrust bearings (Fig. 46).

The use of double gears has the advantage of dividing the load between two worms and gears, thus producing only one-half the strain on each, and securing durability combined with noiseless operation, free from vibration (Fig. 47).

At present there is a tendency in America to replace the tandem worm and gear engine by the single worm and gear, roped two-to-one, but this is, of course, relatively hard on cables.

9. Single Gear with External or Internal Back Gearing.—In buildings where heavy safes (6000 lbs. or more) have occasionally to be handled, back gearing of the spur type may be provided on the engine between the gear and drum shafts, not ordinarily immersed in oil. By this means a relatively small machine may be utilised to lift a heavy load at a lower speed, when the special service is of an intermittent character and first cost is of prime importance.

10. Car Levelling Single Worm and Gear.—One of the latest developments in connection with lift engines is the car levelling gear, that entirely independently of the car attendant or the car loading, will invariably stop the car so that the floor is level with the landing within one-quarter of an inch, high or low. This machine is particularly suitable for hospitals, nursing homes, warehouses, and station platforms in which heavy goods are handled on trucks, etc.

The result is attained in various ways, notably by shunt field control of d.c. motors, by applying a low frequency current to a regular a.c. lift motor or by the use of an additional small-geared machine, arranged to drive the regular hoisting motor and brake shoes at a low speed (Fig. 48).

"The Elevator Interlock Report" (U.S.A. Bureau of Standards already referred to, comments on car levelling devices as follows: ". . . are doubtless the most effective devices available for decreasing accidents from tripping." (See also Chapter III., par. 4.)

11. Location of Winding Engine.—Both drum and vee-sheave machines can be located either in the basement, on any of the intermediate floors, or directly over the shaft. There is a good deal to be said for the basement location, as they are then under closer supervision than when inspection involves a journey to the roof. Certainly when the electrical energy is supplied on the alternating-current system careful consideration should be

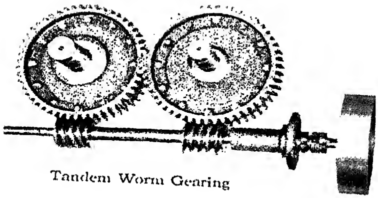


Fig. 46.—Tandem worm gearing.

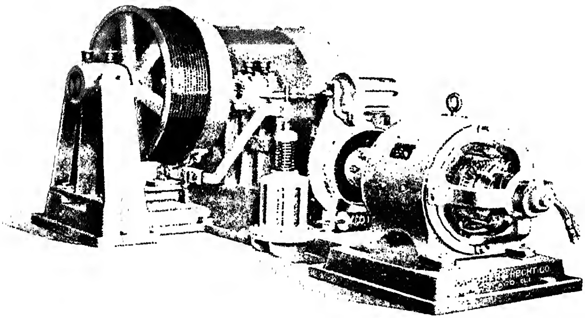


Fig. 47.—Tandem worm gear lift engine.
[*By the courtesy of Messrs. Kaestner & Hecht.*]

[*To face p.* 60

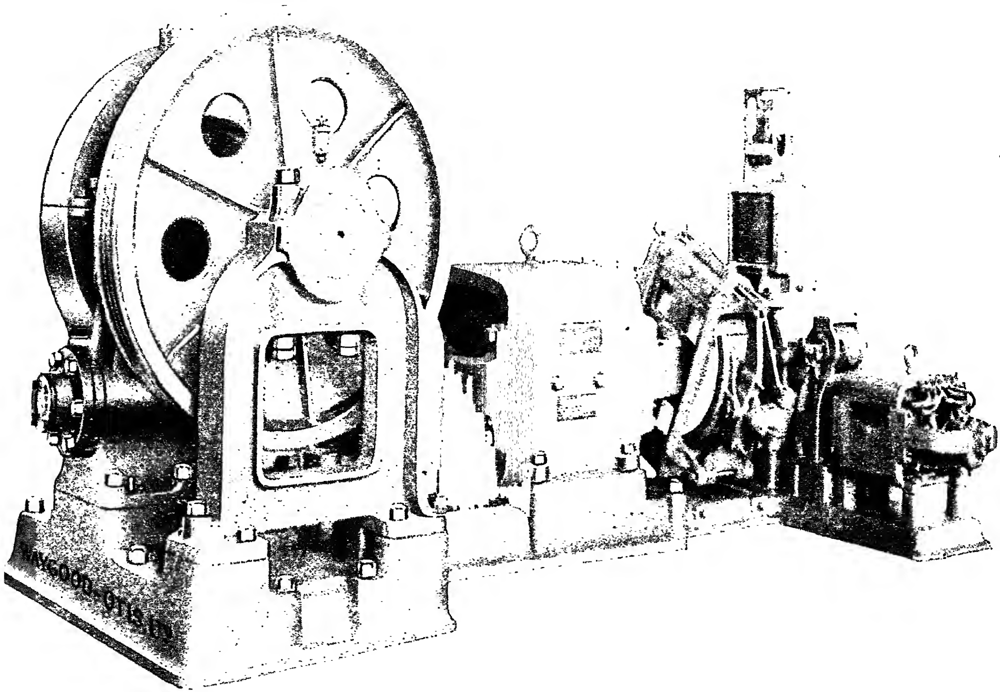


FIG. 48.—Single worm geared winding engine fitted with car levelling device or "micro" drive.

[By the courtesy of Messrs. Waygood-Otis, Ltd.]

[See p. 60.

given to the basement proposition, as the danger of noise from the motors and brakes is then materially lessened and special precautions can be taken in designing the foundations.

Considered purely from the point of view of the ropes and first cost, the most desirable position for a vee-sheave or traction machine, driven by a direct-current motor, is over the shaft, and more are placed in this position than in any other.

Placing the winding engine directly over the shaft imposes a load on the building equal to the weight of the winding engine, plus the load on the car and on the counterweight ropes, whereas, placing the winding engine below imposes a load on the building equivalent to twice the load on the car hoisting and counterweight ropes, therefore, if the winding engine weighs less than the combined goods on the car and counterweight ropes, placing the engine overhead reduces the load overhead. This relation of weights often occurs. [*The author is indebted to Mr. Harrison P. Reed and the American Institution of Electrical Engineers for much of the information contained in this chapter.*]

CHAPTER X.

ELECTRIC MOTORS.

A general knowledge of both a.c. and d.c. motors is assumed and only the special features connected with the application to lifts is discussed. Should further information be required reference should be made to one of the many available books on the subject.

1. Power Required.—In the application of electric motors to lift services it is first of all necessary to ascertain the power required to drive the engine. This obviously depends upon the net load to be lifted, the car speed, and the various friction losses. The power required to get the car in motion—i.e. to overcome the static friction, and to accelerate the mass from rest to full speed—is considerably greater than that required to maintain the car in motion, it being necessary, in certain cases, to apply two and a half times full load running torque,[1] in order to commence hoisting the fully loaded car.

In order to obtain the horse-power rating of the motor which will be required to operate the car at full speed, the following formula may be used :—

$$\text{B.H.P.} = \frac{L \times S}{33000 \times E} \quad \text{when}$$

L = the *net* load to be lifted, allowing for over-counterweighting, which is usually 40 per cent. of the maximum rated car capacity.
S = load speed of car in ft. per min.
E = efficiency of gear (when used) and rope drive, which varies from 40 to about 75 per cent.

For example, the car floor has an area of 25 sq. ft. and the maximum load (on the 75 lbs. per sq. ft. basis) is 1875 lbs. ; 40 per cent. of this load would be 750 lbs., leaving the net load at 1125 lbs. Assuming the car speed to be 200 ft. per min., and the efficiency 47·5 per cent., we get

$$\text{B.H.P.} = \frac{1125 \times 200}{33000 \times 0{\cdot}475} = 14{\cdot}3 \text{ B.H.P. (see also graph, Fig. 49).}$$

[1] Torque, or turning moment, is the product of a force acting on a periphery, and the radius or leverage at which it acts ; thus a force of 1 lb. exerted at a radius of 1 ft. represents a force of 1 lb.-ft.

On direct-current systems, where, within reason, the available starting torque is a function of the current inrush, the size of motor obtained by the above method can be depended upon to start the fully loaded car from rest, but with alternating-current motors, starting torque is a question of design, and so far this

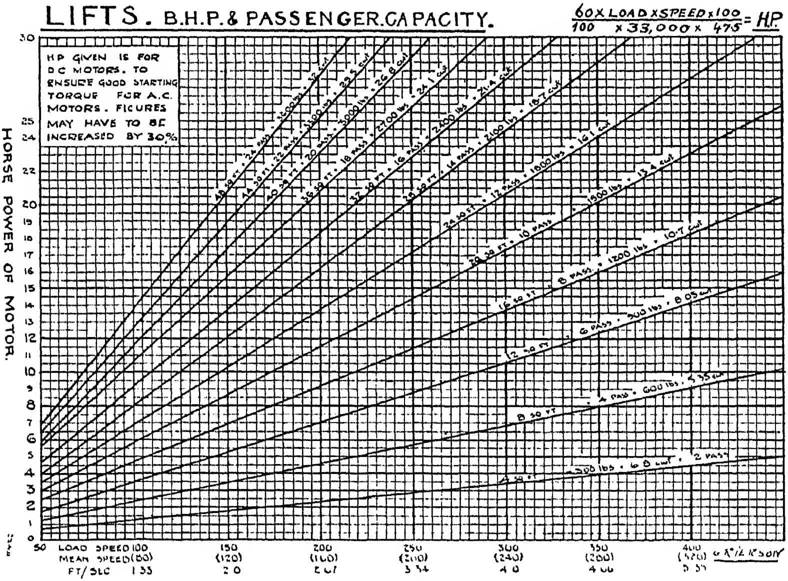


FIG. 49.—Horse-power and passenger capacity.

[*Example*.—Given a car floor area of 24 sq. ft. and a car speed of 200 ft. per min. Required the b.h.p. of the motor.

On one of the diagonal lines it will be noted that 24 sq. ft. equals 12 passengers equals 1800 lbs. equals 18·7 cwts. From the point in the horizontal base line marked 200 ft., ascend vertically to the point of intersection with the diagonal line marked 24 sq. ft. Horizontally to the left, it will be seen that the b.h.p. required is $13\frac{3}{4}$.

Conversely, given a limiting b.h.p. of 10 and a car capacity of 16 passengers, the intersection of these two lines occurs on the vertical line corresponding to a car speed of 110 ft. per min.]

detail has not been standardised. Great care should therefore be exercised in drafting specifications and in conducting take-over tests, to see that the starting torque is adequate to enable the fully loaded car to start easily and smoothly from rest on the upward journey. Not infrequently 30 per cent. is added to the value of the motor horse-power, obtained from the formula or

from the curve in cases where alternating-current motors must be used.

2. **Desirable Characteristics.**—The desirable characteristics of motors to be used for lift work are as follows :—

(*a*) Quiet operation.
(*b*) Good starting torque.
(*c*) Low inertia of moving parts.
(*d*) Good speed regulation under varying loads.
(*e*) Heating in continuous service should not be excessive.
(*f*) Be thoroughly reliable both electrically and mechanically and be designed specially for lift work.

Quiet operation is essential on the majority of passenger lifts and frequently for goods service also; and certain American manufacturers have gone the length of testing each motor in a sound-proof room before despatch to ensure satisfaction on this point.

The necessity for good starting torque has already been discussed.

Satisfactory lift service demands frequent starts and stops, and relatively rapid acceleration and retardation. Flywheel effect therefore must, from this point of view, be low, and this involves armatures or rotors of relatively light weight, small diameter, and correspondingly greater length, revolving at reasonable speed. For single worm and gear the popular speeds are from 1000 r.p.m. for the one b.h.p. motors, down to 650 for the 20 b.h.p. size. On the other hand, if the flywheel effect is too low, the comfort of the car passengers may suffer, as rapid variations in acceleration and retardation then become possible.

Good speed regulation will be seen to be essential when it is remembered that the load may vary from full positive value to some negative value, due to the over-counterbalancing of the car. Thus in the previous example it was assumed that the overbalance would be 750 lbs., and assuming one person only to be in the car at the ground floor, there would be a net weight in the counterbalance of 612 lbs., tending to lift the car without assistance from the motor. Similarly, it is essential that the speed shall not vary materially from the rated speed in lowering a heavy load or the car safety gear may come into action.

Two classes of time rating are recognised for electric motors, i.e. :—

(*a*) Continuous rating.
(*b*) Short time rating (for intermittent working).

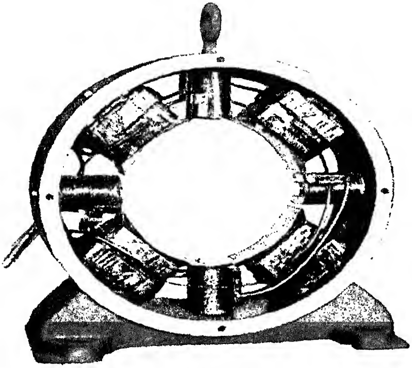


FIG. 50.—Frame of direct-current motor, showing main field coils and commutating or interpoles in place.

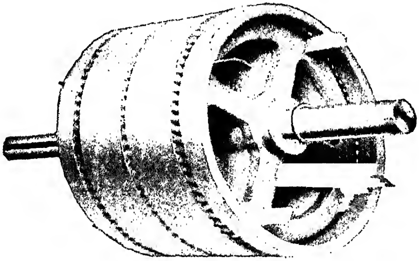


FIG. 51.—Squirrel cage rotor of an induction motor.

[By the courtesy of T. Harding, Churton & Co., Ltd.]

[See p. 67.

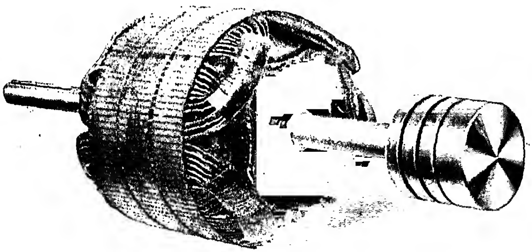


FIG. 52.—Wound rotor of an a.c. induction motor.

[By the courtesy of T. Harding, Churton & Co., Ltd.]

[See p. 68.

[To face p. 65.

The continuous rating is the output that the machine will give for a period sufficiently long to attain a given constant temperature rise. This is usually considered to be six hours.

The short-time rating is the output which a machine will give for one hour, one half-hour, or other specified period, with a specified temperature rise. No standard has been universally adopted for lift motors, some makers offering continuous rating, and others short-time rating. This point should be noted in comparing competitive tenders for which a specification has not been issued.

3. **Direct-current Motors.**—The majority of direct-current motors, whether excited by means of a shunt or a compound winding, are fitted with commutating poles to ensure sparkless commutation (in either direction of rotation) at full load or at the guaranteed overloads, and under conditions of quick reversal (Fig. 50).

Direct-current lift motors are of two general types, i.e. :—

(*a*) Fixed speed.
(*b*) Adjustable speed.

Fixed speed machines are used for goods and for passenger lifts on which the car speed does not exceed 200 feet per minute. If the motor is fitted with a compound winding (shunt and series field combined), the series field, which should represent from 10 to 25 per cent. of the total ampere turns on the main poles of the motor, is used only for starting and is frequently cut out in two steps in order to ensure a constant speed characteristic for the motor. To reduce the speed, in order to ensure accurate stopping at landings, resistances may be inserted both in series and in parallel with the armature, the process being termed dynamic breaking.

Adjustable speed motors are used for passenger installations in which the car speeds range from 200 feet per minute upwards, and under these circumstances the motors are usually provided with a two-to-one speed adjustment. They are generally shunt wound and are started with full shunt field, thus giving the maximum torque. The starting resistance is then cut out at a rate that maintains the starting torque at a constant value.

Adjustable speed, shunt wound motors are advantageously equipped with a short-circuited damping winding on the main poles in order to ensure smooth acceleration by opposing any sudden changes in the field strength. Also it is essential that this type of motor be designed to operate with stable field conditions when running with a weakened field, otherwise, hunting,

or a condition of rhythmic speed variation or beat above and below the normal may develop, a fault with which ventilating engineers are not unfamiliar.

TABLE XIII.

DATA OF TYPICAL ADJUSTABLE SPEED LIFT MOTORS.

B.H.P.	10	15	20	25	30
Max. speed with full shunt (r.p.m.)	450	425	425	425	425
Running speed shunt field control (r.p.m.)	600/900	567/850	567/850	567/850	567/850

A disadvantage of the two-speed motor is that for the same horse-power and maximum speed it must be somewhat larger and more expensive than the single-speed motor.

4. **Alternating-current Motors.**—Alternating-current lift motors have always been regarded as the *bête noir* of the lift industry, but with the increasing utilisation of this system for the distribution of electrical energy, more time and attention has been devoted to the problems involved, in the design of a.c. motors and control gear on both sides of the Atlantic.

Alternating-current motors employed for driving lift engines may be classified according to design, i.e. :—

(*a*) The induction or asynchronous type.
(*b*) The repulsion type.

Or according to the system of supply, i.e. :—

(*a*) Three phase.
(*b*) Single phase.

(The two-phase system of distribution is also employed but it is so rarely encountered, that it is not considered of sufficient importance to discuss in detail, especially in view of the fact that the points made, in connection with three-phase motors, apply almost equally to two phase motors.)

The synchronous speed, or the speed of the revolving magnetic flux, of an induction motor wound either for a single-, a two- and three-phase supply is fixed for a given design of motor and a given frequency of supply. When the supply is given at fifty periods or cycles (written ∼), the possible synchronous speeds, in revolutions per minute, depend upon the number of poles in the machine, and for various machines are as follows :—

TABLE XIV.

POSSIBLE SYNCHRONOUS SPEEDS OF A FIFTY-PERIOD INDUCTION MOTOR.

Pairs of poles .	1	2	3	4	5	6	7
Speed (r.p.m.) .	3000	1500	1000	750	600	500	428

For 60 cycles, take speeds 20 per cent. higher.

The difference in speed between the revolving magnetic flux in the stator or primary circuit and the speed of the rotating shaft is termed "slip." Slip at no load is a minimum and increases with the load, the variation being from 3 to 7 per cent. depending upon the size of the motor.

It will be understood, therefore, that variations in the car speed must be obtained by varying the gear ratio and the diameter of the driving sheave or drum. If the latter happens to be fixed by other considerations, the selection of car speeds is rather limited, since the motor speeds that are found most convenient are of the order of 1000, 750, or 600 r.p.m., or, allowing for slip, 960, 720, and 575 r.p.m.

5. **Three-phase Motors.**—Three-phase motors for lift work are invariably of the induction or asynchronous type, as with this class of supply, designers of these machines have been able to obtain a fairly satisfactory starting torque, for a starting current which need not be unreasonably excessive.

Two main types of three-phase induction motor are available for lift work, i.e. :—

(*a*) The squirrel cage or short circuit rotor.
(*b*) The wound rotor or slip ring.

Unfortunately, squirrel cage motors are not popular with Central Station engineers in the large sizes, as they require from two and a half to three and a half times full load current to develop from one to one and a half times full load torque, and, therefore, cause excessive fluctuations of pressure, when the current is drawn from a combined lighting and power system. In America this type is extensively used up to 20 h.p., because of its simplicity, and because it only requires a relatively simple form of controller (Fig. 51). The motor is frequently thrown across the line, without any starting resistance at all. Where smooth acceleration is essential a resistance or reactance is connected in the stator circuit and gradually cut out after starting, but the speed regulation is not so good as with the wound rotor type.

Wound rotor, or slip ring motors, develop high starting torque (full load with one and a quarter times full load current) without drawing excessive currents from the line (Fig. 52).

Experience indicates that a car speed of 200 ft. per min. is also the limit for single speed alternating-current motors, because no slow-down effect can be obtained under the varying load conditions met with in lift service, and no dynamic brake is at present available to assist the mechanical brake in bringing the car to rest. This means that the magnetic brake (Chapter XI.) must be depended upon to do the work. Since the energy stored in the moving mass is, according to the well-known expression,

$$\frac{WV^2}{2g} \text{ or } \tfrac{1}{2} MV^2,$$

the ideal brake calls for a design based on a similar mathematical principle.

In the dynamic brake, where applicable, the energy is dissipated in the form of heat in resistance grids or frames, the production of heat electrically being proportional to the square of the current (I^2), the current, for a fixed resistance, is proportional to the voltage, and this again is proportional to the speed of the armature. It is, therefore, an important factor in the smooth and rapid retardation and stopping of the car. On the other hand, the magnetic brake is capable only of absorbing energy approximately in direct proportion to the velocity of the moving mass, and hence is not so satisfactory for the present purpose.

Recent work has produced an adjustable speed induction motor which, in certain types, has two stator windings, but in others it has one stator winding that is reconnected to provide a range of speed control.

Another method of obtaining adjustable speed control is by the utilisation of two motors mounted on the same shaft, the smaller of which may be of the squirrel-cage type for slow speeds, the larger being of the slip-ring type for the highest speeds.

Latest information indicates that the limiting car speed, for lifts operated by three-phase motors, has been forced up to 350 ft. per min., but there is no reason to think that finality has been reached, and it is not improbable that further developments may be announced at any time.

6. Single-phase Induction Motors.—The ordinary commercial asynchronous or induction motor, that will operate satisfactorily on a single-phase supply has not yet reached the stage where reversibility and good starting torque can be obtained,

FIG. 53.—Rotor of single-phase repulsion motor.
[*By the courtesy of Messrs. Berkeley & Young, Ltd.*]

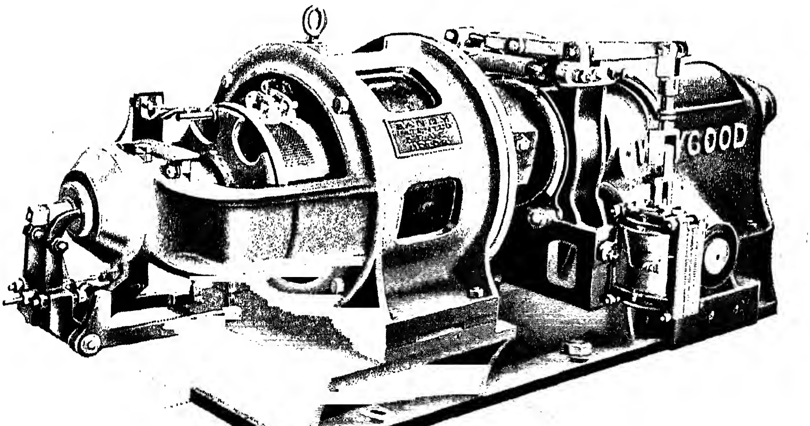


FIG. 54.—" Bandy " single-phase repulsion type motor.
[*By the courtesy of Messrs. Berkeley & Young, Ltd.*]

[*To face p.* 69.

and writers on lifts or elevators have, hitherto, almost invariably avoided the subject.

7. Single-phase Repulsion Motors.—Another type of single-phase machine is available, termed a repulsion motor, but although it has good starting torque it has bad inherent speed regulation. It is, in fact, similar in character to the direct-current series wound motor, and is fitted with an armature, commutator, and brush gear, but in this case the brush gear is short circuited and is not connected to the external circuit (Fig. 53). As in the case of a series-wound d.c. motor, the speed is a function of the load, and should the load be entirely removed the speed may become dangerously high, due to the fact that the torque increases considerably faster than in direct proportion to the current. One method adopted for utilising the valuable feature of good starting torque and of avoiding the unsatisfactory characteristics of this type of motor is to fit a governor to the armature or rotor shaft; that, at the point of synchronous speed, connects all the commutator bars together, and at the same time throws the brushes out of contact with the commutator, thereby producing practically a squirrel cage, single-phase induction motor which then runs slightly below synchronous speed.

If the brushes of the plain repulsion motor, first described above, are shifted into various positions relatively to the stator coils, the motor can be caused to rotate in either direction or to stand still, when the stator windings are connected to a source of single-phase power. In other words, maximum torque can be produced in either direction, or zero torque can be produced at will, merely by shifting the brushes.

This principle has been applied very successfully in practice in the well-known "Bandy" motor. With this machine practically constant speed can be obtained by means of an automatic governor that regulates the position of the brushes relatively to the stator windings, whereby the torque developed is just sufficient to balance the load. Any increase in load tends to produce a fall in speed, whereupon the governor will rock the brushes into a position of increased torque (i.e. farther from the neutral point or position of zero torque), and the speed will be adjusted to the predetermined value (Fig. 54).

In the case of motors that are required to run in either direction, the reversal can be obtained either mechanically or electrically. In the former it is effected by connecting the brush rocker, by means of link motion, to a small countershaft on which is mounted a wheel to which the hand rope of the lift car

may be attached. The position of minimum starting torque is about ten electrical degrees either side of the neutral position so that the total travel of the rocker is only about 20°.

Electrical reversal is the more usual form for passenger lifts, and in this design the motor is supplied with two-phase windings, the phases being of unequal turns. The two-phase windings are put in series, thereby producing a single-phase winding, and reversal is effected by reversing one winding relatively to the other by means of a reversing switch. Under these circumstances it is unnecessary to rock the brushes in order to obtain reversal, since the change in the stator winding connections moves the fields relatively to the brushes, and these, in consequence, have a fixed position when at rest.

At starting the brushes are located in the position for maximum torque, and hence maximum line current to the stator, and the whole effect of the governor is to reduce the torque, and hence the line current as the motor runs up to speed. Any failure of the governor, therefore, will have no tendency to increase the current or to blow the fuses, and the risk of imprisoning passengers in the car, due to a failure of the governor gear, therefore disappears.

Other points in favour of this motor are that it is independent of synchronous speed—70 per cent. to 90 per cent. synchronous speed being usual—good power factor is obtainable, i.e. from 0·8 to 0·9 (twice full load torque can be obtained with one and a quarter times full load current in special cases, if required); and the speed regulation from full load to no load is approximately 7½ per cent.

Whether a.c. or d.c. motors are utilised for driving the lift winding engine, the outer end of the motor shaft should always be extended through the bearing for a distance of 2 or 3 ins. and cut with a square-faced end, so that a crank handle may be fitted and the shaft rotated by hand should this be necessary at any time in the event of a failure of supply, to release passengers who may be in the car.

8. Installation of Motor Generators and Rectifiers.—A simple method of avoiding all the difficulties that are experienced when alternating current must be employed is to install motor generators or rectifiers and convert the alternating-current supply into direct-current, but the plant adds very considerably to the capital cost, provides additional possibilities of failure, and increases the maintenance and operation charges.

9. Methods of Speed Control.—The methods adopted for adjusting the speed of a motor are closely associated with the arrangement employed for accelerating the motor from rest to its lowest operating speed and they may assist materially in smoothing it out (see Chapter XII.). The principal methods are as follows :—

(*a*) Adjustment of the field strength on a d.c. shunt wound motor.

(*b*) The connection of resistances in series and in parallel with a d.c. motor armature.

(*c*) The application of a variable voltage to the terminals of a d.c. motor.

(*d*) The application of several different voltages to the terminals of a d.c. motor.

(*e*) Changing the number of poles of an a.c. three-phase motor.

(*f*) Changing the frequency of the supply to an a.c. motor.

10. Adjustment of Strength of Shunt Field.—With constant voltage at the commutator brushes, the speed of a direct-current, shunt wound motor varies practically in inverse proportion to the change of field magnetism, that is, the weaker the field, the higher the speed, and vice versa. The field magnetism changes with any change of the shunt field (excitation) current, though not always in direct proportion.

The range of speeds obtainable with this method depends upon the design of the motor, 10 per cent. being usually regarded as the maximum for a standard type, not fitted with interpoles. If a larger range is desired, the machines must be specially designed for the purpose, in order to secure stable operation at the higher speeds, and a larger and more expensive frame size is necessary.

If the motor is massive and responds slowly to a change in field strength, little difficulty is introduced by this method, but if it responds quickly, relays or other devices must be used to limit the current surge, during the change in speed. Since the field current rarely exceeds 3 per cent. of the main current, the rheostatic losses, when this method is utilised, are extremely small, and therefore the system is a very economical method of speed control.

11. Resistances in Series and in Parallel with a D.C. Motor Armature.—A resistance connected in parallel with a

d.c. compound wound motor armature has a stabilising influence and limits the speed variation under different conditions of landing. This method is commonly used for obtaining the low speed from which a landing is made. It is the least economical system and its use therefore is restricted, as a rule, to the purpose stated.

12. Application of Variable Voltage to the Armature of a D.C. Motor.—In certain cases, special generators have been provided for each lift motor and, under these circumstances, the lift motor can be operated from rest to full speed in either direction merely by changing the strength and the direction of the generator field.

13. Application of Several Different Voltages to the Armature of a D.C. Motor.—Where a battery of lifts is to be installed it is possible, but hardly probable, that it might be desirable to consider the question of utilising several generators driven by one motor, each generator giving a different voltage, to provide a simple means of speed control. Alternatively a five-wire balancer might be used on a 500-volt circuit to provide different pressure values. In either case, the transition between voltages would be taken care of by armature resistances, and the armature connections would require to be reversed in order to reverse the direction of rotation of the motor.

14. Changing the Number of Poles of an A.C. Motor.—Since the speed of an alternating-current induction motor depends upon the frequency at which the supply is operated and the number of pairs of poles on the motor, it is obvious that, assuming the former value to be constant, the speed can be changed if it is practicable to obtain different pole combinations. Recent progress has made such motors available, provided with the combination of a large number of poles giving a low speed from which the landing is made and a smaller number of poles for the normal operating speed. The stator may have two sets of windings, one for each set of poles, or a single set arranged for two sets of connections. (See also Chapter X.)

15. Changing the Frequency of Supply to an A.C. Motor.—As an alternative to the above method it is possible, by installing a frequency changer to utilise a standard induction motor and to obtain the low speeds from which the landing is made, by connecting it to the stator winding.

CHAPTER XI.

MAGNETIC AND DYNAMIC BRAKES.

1. Location and Function of Magnetic Brakes.—On practically all makes of single and tandem worm gear engines, the coupling between the motor and the worm shaft forms the drum on which the braking effort is applied, but in the gearless traction type a special brake wheel, that may form part of the vee sheave, is directly mounted on the armature shaft (Fig. 36).

Although the design may vary, the function remains the same, i.e. rapidly to absorb the momentum or the kinetic energy stored in the moving parts so that smooth and accurate landing stops may be made from comparatively high car speeds, with the minimum loss of time.

2. General Arrangement.—The brake shoes, usually two in number and semi-circular in shape, are faced with woven asbestos or other special brake linings, and are held up to the drum or wheel by means of powerful springs and levers. The levers are coupled to the armature of a powerful electric magnet or to the plunger of a solenoid, the coils of which are so connected that the brake is released immediately current is switched on to the motor. Conversely, a failure of power always stops the lift and applies the brakes automatically (Fig. 54).

Preferably, the two halves of the brake shoe should be entirely independent of each other, so that either part is a complete brake in itself, and will be effective on the failure of the other half.

Whatever type of brake is employed, it should be designed for easy and accurate adjustment, so that wear in the shoe linings can be taken up from time to time and satisfactory operation ensured.

3. Release for Hand Winding in an Emergency.—Means should always be provided for releasing the brake, in the event of failure of the motor or the supply current, so that the crank handle can be applied to the motor shaft and the car, if of reasonable size, may be wound by hand to the nearest floor level.

4. **Retarding Torque.**—It is usual to select a brake that will provide a retarding torque at least equal to the full load torque transmitted by the motor, the approximate value of which can be obtained from the expression :—

$$T = \frac{\text{B.H.P.} \times 33000}{2\pi N} = \frac{\text{B.H.P.} \times 5252}{N}$$

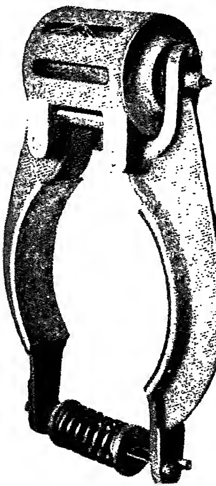
when T = torque in pounds-feet,
N = revolutions per minute.

5. **Types.**—With direct-current supply the problem of satisfactory design is a relatively simple one, but on alternating-current systems it becomes complicated due to the difficulties encountered in designing a satisfactory magnet. Various types of magnets are being employed, such as single-phase long stroke, polyphase long stroke, polyphase short stroke, and constant stroke.

One of the greatest difficulties experienced in producing a satisfactory a.c. brake is noiseless operation. They are liable to slam when closing, and unless the laminated parts are perfectly surfaced and perfectly aligned they will hum after closure. On some types dash pots are used, and certain makers immerse the entire magnet in oil to deaden the noise (Fig. 56).

6. **Dynamic Brakes.**—Reference has already been made to dynamic braking (Chapter X.) in connection with three-phase motors, and it is also referred to in Chapter XII. in connection with control gear.

The method, which can only be applied to installations in which direct-current motors are employed, depends upon the fact that when the current supplied to a d.c. motor, that is running at or about full speed, is switched off the armature continues to rotate for an appreciable period of time due to the kinetic energy stored in the moving parts. Provided the field is excited current will flow through any circuit that is connected to the armature terminals, and if this circuit takes the form of a resistance frame, the energy stored in the moving parts will be dissipated in the form of heat. Obviously, under these circumstances the retarding effect can be given any desired value, merely by adjusting the resistance that is placed in circuit.



—Magnetic brake (direct current).

courtesy of Messrs. Kaestner & Hecht.]

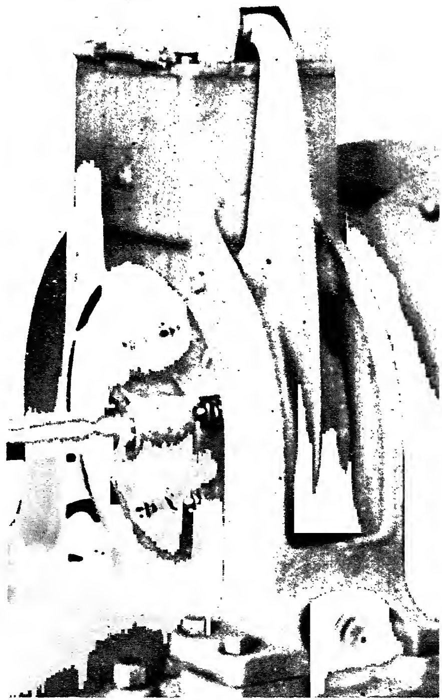


Fig. 56.—Oil-immersed magnetic brake (alternating-current).

[By the courtesy of Messrs. Waygood-Otis, Ltd.]

[To face p. 74.

CHAPTER XII.

CONTROL GEAR.

1. Functions of Controller.—Modern lift control panels are called upon tens and possibly hundreds of thousands of times per year to perform the following cycle of operations in either direction of travel and with widely varying loads in the car :—

(*a*) Start the car from rest and accelerate smoothly to full speed.

(*b*) Operate the car satisfactorily at full speed.

(*c*) Retard smoothly from full speed and stop the car accurately at the landing.

(*d*) Hold the car stationary while it is at the landing.

The design of the controller affects the energy consumption to a marked extent, and considerable economy can be effected by selecting the most suitable type for each particular application. Needless to say, safety and reliability are the essential features, and the necessity for simplicity and robust construction is obvious. Silent operation of controllers, fixed in connection with passenger and service lift or dumb waiter equipment, is highly desirable in the majority of installations and essential in flats, residences, hotels, offices, and similar buildings. Accessibility for inspection and prompt repairs, when so many human lives depend on details, is not only desirable but also absolutely essential.

The car attendant or passenger can only select the direction in which the car is required to travel, and afterwards, on a multi-speed lift, select the required operating speed. All other operations are carried out by and on the main control panel, which is usually fixed in the engine room, adjacent to the winding engine.

2. Parts of Controller Equipment.—The controller equipment consists of :—

(*a*) The operating car device, which may be either a hand rope, car switch, or a box containing a series of push buttons.

(*b*) The main control panel that carries the reversing switch, starting rheostat, etc., which is usually fixed in the motor room.

(*c*) The magnetic brake (already discussed).

(*d*) The shaft "slow down" and ultimate limit switches. } To be discussed under Safety Devices.

(*e*) Door and gate interlocks.

3. Methods of Operating the Motor Controller.—The motor controller may be operated from the lift car or the landing in several different ways, i.e. :—

(*a*) Hand rope.
(*b*) Car switch.
(*c*) Push button.
(*d*) Combined car switch and push button.

4. Hand-rope Control.—Hand-rope control was the earliest method adopted for operating electric lifts and is now almost obsolete, except possibly for cheap, slow-speed goods or freight lifts. It was probably suggested by the rope control employed for operating the supply and waste valves utilised in hydraulic lift work.

The hand rope, which passes through the car, reaches from the top to the bottom of the shaft and is arranged to start, stop, and to reverse by operating the spindle of a switch (fixed on the main control panel) depending upon the direction and the distance the rope is pulled (Fig. 57). The rope is fitted with two stops, one at the top and one at the bottom landing, together with a stretching device to keep the rope taut. In the event of the attendant failing to stop the car when near the upper or lower landing, the car eventually comes into contact with one of the above-mentioned stops on the hand rope, and the car is stopped automatically.

A lever or hand wheel may be used for manipulating the rope in order to avoid the necessity of the attendant or passenger hauling on it directly. Another variation, occasionally to be seen on the Continent, consists in the provision of a series of buttons, corresponding to the floors. On entering the car the passenger presses the button marked with the floor that he desires to travel to. The rope is then pulled, and on arrival at the selected landing a claw or stirrup, forming part of the push-button spindle, engages with a stop attached to the rope, thus bringing the car automatically to rest.

5. Car-switch Control.—The most satisfactory method of operating the car in a modern high-speed multi-car installation running on the schedule system is the car switch. The movement of the car-switch handle to either side causes the car to travel either up or down, according to the method of connection

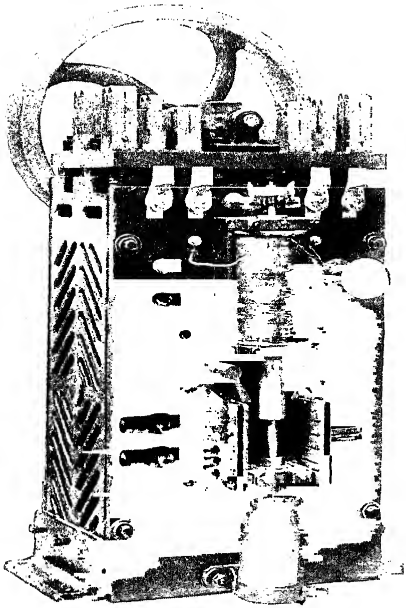


FIG. 57.—Hand rope controller.
[By the courtesy of Messrs. Marryat & Scott, Ltd.]

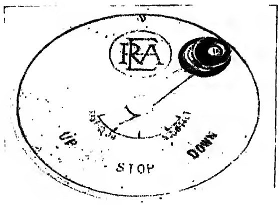


FIG. 58.—Car switch (two speeds).
[By the courtesy of Messrs. R. A. Evans, Ltd.]

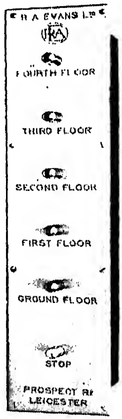


FIG. 59.—Car push button.
[By the courtesy of Messrs. R. A. Evans, Ltd.]

[See p. 77.
[To face p. 76

adopted, and on multi-speed lifts the desired speed can also be selected. The handle should be invariably of the *dead man* or self-centering type, i.e. it returns to the "off" position, which should be very definite, immediately the hand is removed from the control handle.

The control handle should be detachable, so that the attendant can retain possession of it, and the car, in the absence of the attendant, cannot be operated by an unauthorised person. On single-speed lifts there are only three positions for the handle, i.e. "Up," "Down," and "Stop," the work of releasing the brake, operating the reversing switch, accelerating switch, etc., being entirely automatic once the car switch has been moved into the selected position.

For two- and three-speed lifts, the car switch is similar to that described above, except that between the "Stop" and the "Full Speed" points there are one or more intermediate positions to which the handle or key may be turned, according to the speed desired (Fig. 58).

The car switch, which should be of neat design, substantial in construction, and finished to match the decorative work of the car, is connected to the magnet-operated switches, mounted on the control panel or switchboard, by means of a flexible cable formed of the requisite number of insulated conductors.

A desirable feature to standardise would be the car-switch connections, so that the movement of the handle or key towards the door or front of the car would cause the car to travel downwards, and a movement in the reverse direction would cause it to travel upwards.

6. Push-button Control (Full Automatic and Semi-automatic).—Another method of operating the main control panel from the car is known as Push-button Control.

A push button is located at each landing termed the "Call Push," and inside the car a plate is fitted carrying a series of buttons, one button corresponding to each landing. Provided the car is not in use and all doors and gates are closed, it is called to the floor at which the passenger is waiting by pressing the "Call Push" at that landing. On arrival, both the landing doors and the car gate locks are released and the gates can then be opened and closed by the passenger. The button corresponding to the landing or floor required is then pushed by the passenger in the car, the result being that the proper connections are set up in the main control panel to move the car to that particular landing and automatically to stop it on arrival (Fig. 59).

Where this method of control is employed a floor switch, connected in circuit with the landing push buttons, is often fixed in the car, so that immediately a passenger enters the car his weight automatically operates the switch, thereby disconnecting all landing "Call Pushes" and placing him in sole control.

This type of control has a particular field of application for passenger cars in private houses, flats or apartment houses, small hotels, Government and similar buildings, where the traffic (either tenants or visitors) does not warrant the expense of a regular attendant or operator. The limiting car speed is usually considered to be not more than 160 ft. per minute, unless a two-speed controller is provided.

A variation of the method described above, termed semi-automatic, includes for only three push buttons in the car, irrespective of the number of floors served, marked "Up," "Down," and "Stop." Assuming the car is at an intermediate landing, momentary pressure on either of the first two buttons starts the car and the movement continues until the "Stop" button is pressed or the car arrives at the upper or the lower landing, where it comes into contact with a "Stop" switch, or landing limit switch, fixed in the shaft. It is a cheaper system than the full automatic type first described and is suitable also for car speeds up to 160 ft. per minute, although possibly 130 ft. per minute is more desirable. It is chiefly employed in connection with goods or freight lifts.

Either form of push-button control is necessarily more elaborate than the car-switch type, and as such it is probably slightly less reliable. For buildings where passengers may simultaneously require the lift, it is certainly a time and power waster, because so many trips are made with light loads and without regard to floor demands, i.e. the first person who presses the button may receive and retain the exclusive use of the car until he has completed the journey, irrespective of all other passengers who may desire to travel and who may actually be passed on the trip.

7. Combined Car-switch and Push-button Control.—A combination of car-switch and push-button control may be advantageously employed in certain installations in which the traffic justifies the employment of an attendant for only part of the time that the car must be in service, e.g. large blocks of flats or apartment houses, clubs, and certain office buildings of considerable height.

The first cost is higher than any other type but the saving

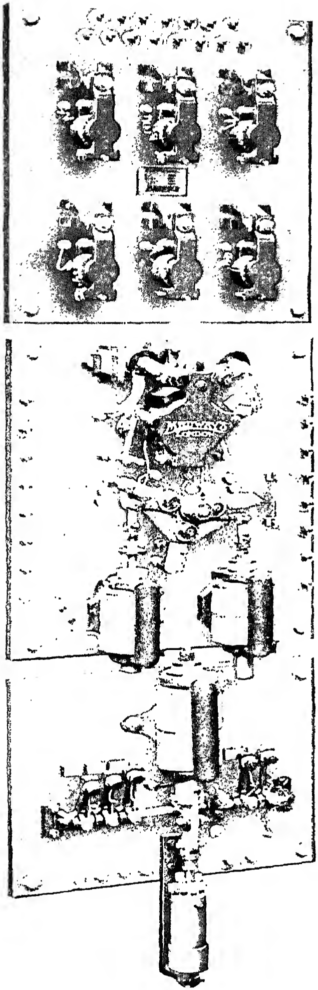


FIG. 60. Full automatic d.c. push-button controller for 6 b.h.p. motor.
Top panel : six floor relays. Centre panel : Main breaker and reversing switch.
Bottom panel : Solenoid rheostat.

[*By the courtesy of Messrs. Medways, Ltd.*]

[*See p.* 79.

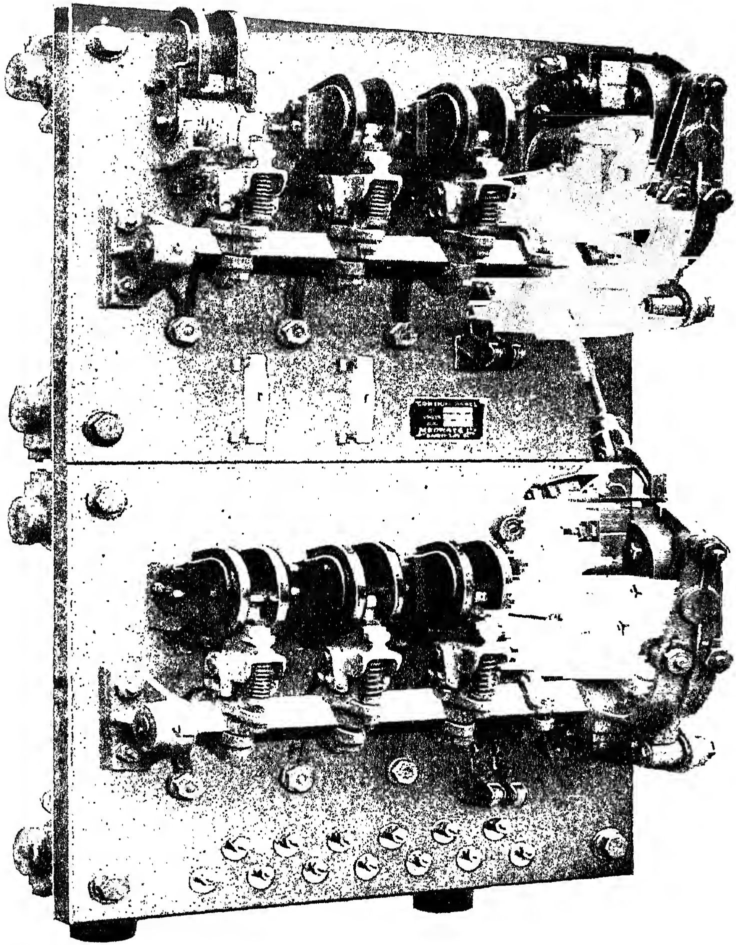


FIG. 61.—Reversing switch for stator circuit of three-phase motor, showing mechanical interlock.

[*By the courtesy of Messrs. Medways, Ltd.*]

[*To face p.* 79.

in wages will, in many cases, justify its adoption. A special change-over switch is provided whereby the conversion of the control is effected from car-switch to push-button and vice versa. In the majority of installations in which this method is employed it will be found desirable to provide for at least two speeds on the car switch, so that the car may be operated at high speeds during the day and single speeds on the push-button control, as this will only be utilised when the traffic is relatively light and at times when the car speed is of secondary importance to convenience.

8. **Main Control Panel.**—The equipment usually found on the main control panel or adjacent thereto is as follows :—

(*a*) The main reversing switch.
(*b*) A main starting resistance or rheostat.

Varying with the make of control panel installed, the type of operating device employed, and the system on which electrical energy is supplied to or generated in the building, the following additional items may be found :—

(*c*) Speed controller (multi-speed lifts).
(*d*) Relays and resistances for the dynamic brake.
(*e*) Protection against overloading the motor or the control circuit.
(*f*) A magnet-operated double or triple pole main switch (d.c. and three-phase supply respectively)
(*g*) A floor selecting device (push-button control).
(*h*) Local car operating switches.
(*i*) An ammeter, a voltmeter, and an integrating watt hour meter.
(*j*) Protection against phase failure } alternating current
(*k*) Protection against phase reversal } supply only.

Each type of lift requires its own special form of control panel and details differ very considerably.

9. **Main Reversing Switch.**—This is employed to reverse the direction of rotation of the motor, so that the car may travel in the upward and in the downward direction respectively. For modern direct-current motors it is almost invariably connected in the armature circuit (Fig. 60), but for three-phase motors, two of the three main stator leads are reversed (Figs. 61 and 62). The reversal of single-phase motors has already been dealt with (Chapter X.).

In certain types the switches are electrically interlocked and

in others they are mechanically interlocked, the result aimed at being the same in both cases, i.e. to prevent a short circuit due to both switches being closed at the same time.

Care must be taken to avoid any danger to the windings by reason of disruptive discharge from the shunt field coils. Some makers employ a non-inductive wire or lamp resistance and others have secured patents for various ingenious devices of which details can be obtained from their catalogues.

10. Main Starting Resistance.—Both with direct-current and with three-phase motors, resistances or their equivalent are required in the armature or in the rotor circuits to limit the current drawn from the mains during the period of acceleration.

There is a notable difference in design between English and American starting resistance switch gear as will be observed from the illustrations of various types. The English makers almost exclusively retain the multi-contact radial arm or vertical pull type of starting rheostat for direct-current equipment (Fig. 63) and utilise the clapper or magnet switch chiefly for the rotor starting rheostat of alternating-current motors. On the other hand, American manufacturers almost exclusively use the clapper switch for both direct and alternating-current motors (Fig. 64).

There is little published information available regarding the standard rates of acceleration of passenger lift cars, and although the problem is somewhat different, it may be interesting to note that in electric railway practice a figure of 3 ft. per sec. per sec. is regarded as the maximum for either process, having regard to the comfort of passengers, although when stopping in emergencies this value may often be doubled.

Utilising the well-known expressions employed in connection with problems of acceleration and retardation, we have

$$(a)\quad t = \frac{v - u}{f} = \frac{2s}{u + v},$$

$$(b)\quad s = ut + \tfrac{1}{2}ft.^2 = \tfrac{1}{2}t(u + v),$$

$$(c)\quad f = \frac{v - u}{t},$$

where

t = time in secs., v = final velocity (ft./sec.),
u = initial velocity (ft./sec.), s = space traversed (ft.),
f = rate of change of motion (ft./sec./sec.).

Assuming a car speed of 200 ft. per minute (3·33 ft./sec.) and an acceleration period of 5 secs. we obtain for

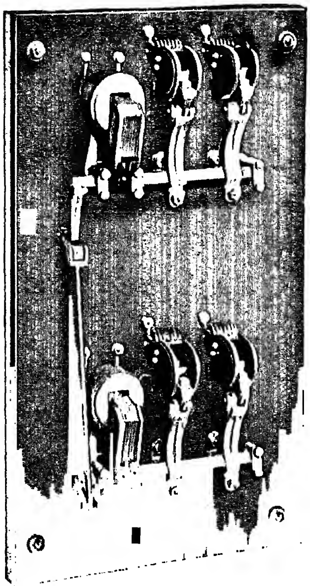


FIG 62.—Reversing switch for stator circuit of small three-phase motor. Contactors for two of the three phases only—one phase left connected continuously.

[*By the courtesy of Messrs. Electric Control, Ltd.*]

[*See p.* 79.

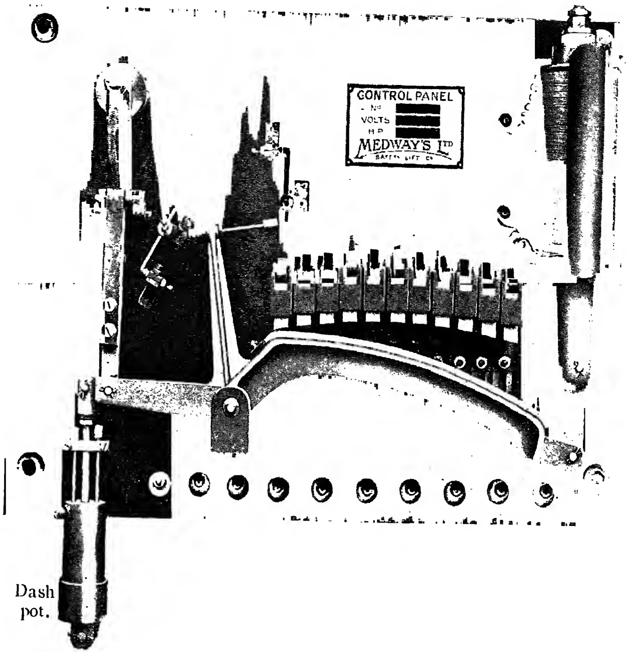


FIG. 63.—Direct-current armature rheostat operated by long stroke solenoid.

[*By the courtesy of Messrs. Medways, Ltd.*]

[*To face p.* 80.

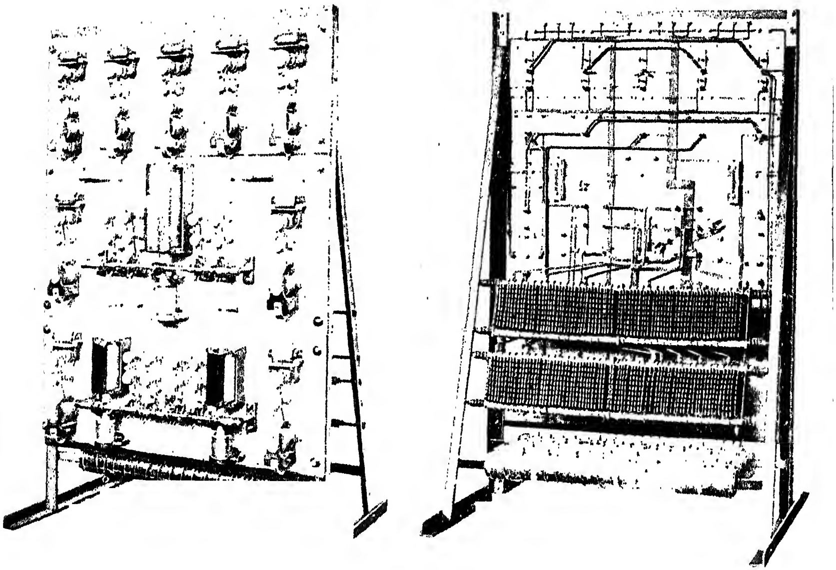


FIG. ›eed control panel 300/600 ft./min. car switch control.

Top panel: (L. to R.) 1, 2, 4 and 5 line switches; (centre) field switch. Centre panel: (centre) armature resistance, first speed; (left) auxiliary shunt field switch for high starting torque; (right) dynamic brake. Bottom panel: second and top speed switches and cut-outs.

[*By the courtesy of Messrs. Kaestner & Hecht of Chicago.*]

[*See p.* 80.

1. *Space traversed during period of acceleration:*

$$s = \tfrac{1}{2}t(u + v)$$
$$= \tfrac{1}{2} \times 5(0 + 3{\cdot}34) = 8{\cdot}35 \text{ ft.}$$

(N.B.—This example clearly illustrates the futility of installing high-speed lifts for a purely local service when stops are made at each landing that may be 10 to 15 ft. apart.)

2. *Rate of acceleration:*

$$f = \frac{v - u}{t} = \frac{3{\cdot}34 - 0}{5} = 0{\cdot}67 \text{ ft. per sec.}$$

Apart altogether from the passengers, the motor armature or rotor must be given sufficient time to accelerate, for otherwise the currents flowing through the windings may rise to a dangerous value if the starting rheostat be cut out too rapidly. The time required safely to accelerate the armature or rotor depends upon the size of the motor, a standard ordinary duty rating for industrial motors being 5 secs., plus $\tfrac{1}{2}$ sec. for each b.h.p. of the starter rating, i.e. 5 b.h.p. in $7\tfrac{1}{2}$ secs., 15 b.h.p. in $12\tfrac{1}{2}$ secs., 30 b.h.p. in 20 secs., provided current surges do not exceed 150 per cent. full load current. For heavy duty the period of starting up is extended to one minute.

The principal methods employed for controlling the period of acceleration of the motor are discussed in the following paragraphs.

11. Time Element Method of Controlling Period of Acceleration.—In this method, either air or oil dash-pots are employed that retard the motion of the rheostat arm or switches for a definite period of time without reference to the current value. Its chief feature is smooth and even starting under all conditions of loading since sufficient resistance can be provided to start with a light load. With a heavy load, sections of the resistance are successively cut-out until sufficient torque is developed by the motor to accelerate the load. It will be noted that by this method the value of the current that may flow is only limited by the fuses or other protective devices.

12. Counter or Back E.M.F. Method of Controlling Period of Acceleration.—This method depends for operation upon the principle that with a direct-current motor the voltage across its terminals increases as the speed rises. Magnet-operated switches connected across the terminals and designed to operate at predetermined pressure values can be arranged to close in succession and to short circuit sections of the resistance. This

method provides protection for the motor, but the rate of acceleration is obviously a function of the load. The first contact must be designed so that the resistance in circuit permits sufficient current to flow to enable the motor to develop the starting torque required for the maximum load.

13. Current Limit Method of Controlling Period of Acceleration.—If the principle of constant torque is employed for acceleration, the rheostat must be given resistance values that allow the stationary motor to draw sufficient inrush current from the line to develop the torque necessary to commence lifting the maximum load. Since the running friction is considerably less than the static friction a large portion of the motor torque rapidly becomes available for accelerating the load, and the motor increases in speed until the torque developed is just sufficient to balance the load. At this current value a relay closes the contacts to the next accelerating switch which, in turn, accelerates the motor to a higher balance speed, the process being repeated until all of the starting resistance has been cut-out. In this case also the rate of acceleration is a function of the car load, since the motor reaches full speed more rapidly with a light than a heavy load.

14. Eddy-current Method of Controlling Period of Acceleration.—The principle of eddy currents is also employed for controlling the period of acceleration upon a current limit basis, both for direct and alternating-current motors.

In the former case a copper disc is mounted between the poles of an electro-magnet which is excited by the main current. To this disc, by means of suitable gearing, the moving arm of the rheostat is attached, and the retarding effect is at maximum value when the main current is also at maximum value. Simple and ample starting time adjustment is provided (Fig. 65).

For alternating-current motors having three-phase wound rotors, an eddy-current controller is provided, consisting of three solid steel cores having insulated copper windings from which tappings are taken to the rotor slip rings. On starting the motor, the rotor current is forced through the controller at line frequency and the maximum rotor volts, and, therefore, produces the maximum eddy current loss. As the motor speeds up, the voltage and frequency of the rotor currents decrease in proportion, and, consequently, the eddy current losses decrease automatically (Fig. 66).

The rate of acceleration may be also modified by altering slightly the design of the magnet switches, i.e. giving them

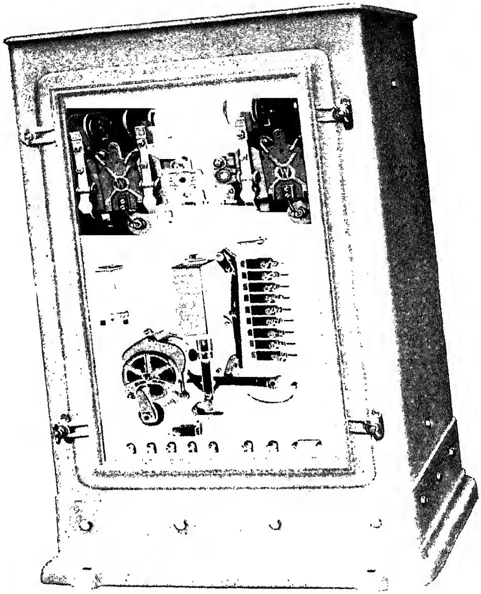


FIG. 65.—Direct-current control panel (car switch) in which period of acceleration is controlled by an eddy-current brake.

[*By the courtesy of the Walford Electric and Manufacturing Co., Ltd.*]

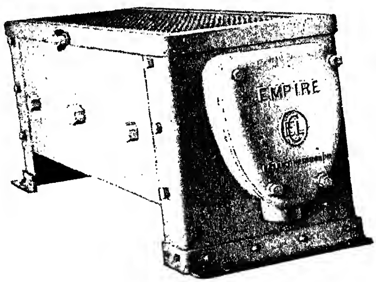


FIG. 66.—Eddy-current rotor controller.

[*By the courtesy of Electric Control, Ltd.*]

[*To face p.* 82.

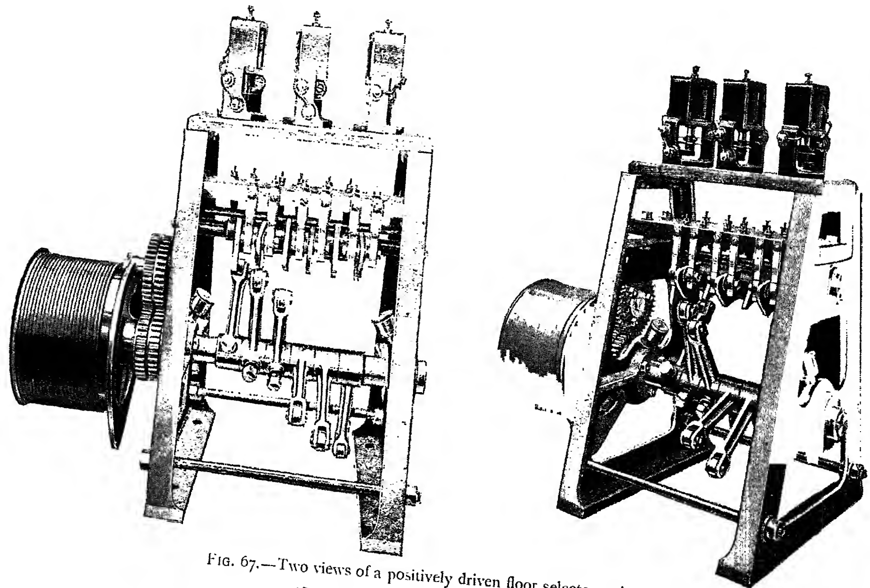


FIG. 67.—Two views of a positively driven floor selector switch.

[By the courtesy of the Express Lift Co., Ltd.]

[See p. 83.

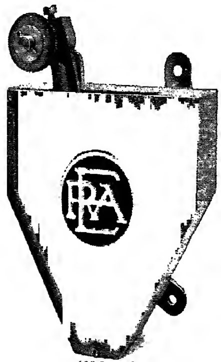


FIG. 68.—Shaft tappet switch.

[By the courtesy of Messrs. R. A. Evans, Ltd.]

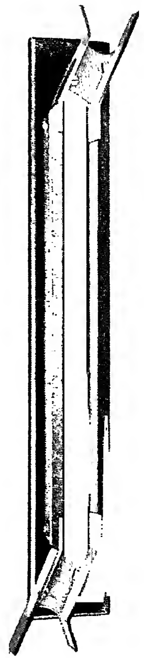


FIG. 69.—Cam for operating shaft switch.

[To face p. 83.

greater or less inertia, by increasing or reducing the inductive effect either in the circuit by means of impedance or choking coils, or by a special design of motor, or the time element of the motor may be increased.

15. **Speed Controller.** — Consideration of the description given in Chapter X. of the various methods employed for speed control will clearly indicate that it is not possible to discuss the control gear in detail, as it differs practically in each and every lift.

16. **Relays and Resistances for Dynamic Brakes.**—The equipment employed in connection with the dynamic brake is usually of a simple character, consisting merely of resistance frames and one or more relays or magnet switches that connect the armature to the resistance, after the main current is disconnected.

17. **Protection Against Overload.**—For small, low-voltage motors the protection may be in the form of fuses, but for the larger, high-voltage motors circuit breakers or trip coils operating the main switches are desirable.

18. **Magnet-operated Main Switches.**—In addition to the main reversing switches many makers equip the control panels for the larger motors with a magnet-operated double pole or triple pole main switch, according to the system of supply, on which current is invariably made or broken.

19. **Floor-selecting Devices** (push-button control).—Two principal methods are employed for floor selection on lifts equipped with push-button control, e.g. :—

(*a*) Selector switches.
(*b*) Tappet switches.

By the use of a selector switch that is positively driven, either from the winding engine (drum type) or from the car, the floor-setting mechanism and the contacts connected therewith are grouped in the engine-room and are therefore under direct observation. There is also the additional advantage that limit switches and striking planes or ramps are not, with this system, necessary in the shaft, so that should the lift be fixed in the well of a staircase there is nothing unsightly (Fig. 67).

Possibly a cheaper method is to locate tappet or direction switches (Fig. 68) in the shaft, one at the level of each floor, and to operate them by means of metal or hard-wood ramps or striking planes securely fixed to the car (Fig. 69). The chief objections to this system are the difficulties connected with the

examination and cleaning of the switches and the noise which, although it may be reduced to a minimum, is caused by the ramps or striking planes operating the switches during the travel of the car.

Whichever method of floor selection and levelling is adopted, relay switches are provided on or adjacent to the main panel equal in number to the floors served.

The function of these selector, tappet, or direction switches is, of course, to select the direction in which the car is to travel when the "Call" push on—say the third-floor landing—is pressed and to stop it at the landing on arrival. If the car is at the top of the shaft it will travel down, and if in the basement it will, of course, travel up to the third floor and stop on arrival at that landing.

20. **Local Car Operating Switches.**—Means are frequently provided, whereby the control can be transferred from the car to the main control panel, so that after cleaning, overhauling, repairs, etc., the car can be conveniently started, stopped, reversed, etc., and the operation of the brake, gears, motor, switches, relays, etc., carefully checked and noted.

21. **Ammeters, Voltmeters, and Integrating Watt Hour Meters.**—Each of these instruments form a very useful addition to the essential equipment of any main control panel. The ammeter enables the effect of the balance weight on the up and down trip, with average car loads, to be checked, and the current taken during the period of acceleration to be noted. The voltmeter is a useful check on the supply pressure, in the event of anything unusual occurring in the operation of the motor, and the integrating watt hour meter provides a record of the electrical energy used per day, per car mile, or on any other convenient basis that may be adopted.

22. **Protection Against Phase Failure.**—Phase failure protection devices are only necessary on two- and three-phase motors. The desirability for employing this equipment is due to the fact that in a three-phase motor three separate windings each contributes its quota of power to the motor shaft and hence to the driving sheave and to the ropes. On a three-phase motor in the event of failure of one conductor, which puts two phases out of action, the remaining phase, fed by two of the conductors, is heavily overloaded, and, unless the motor is stopped, excessive heating and eventually the failure of that phase winding would occur.

Protection can be secured by inserting trip coils or relays in

two of the phase leads, the action of the coil being delayed by a time-lag device of the oil dash-pot, eddy current, or similar type. By this means no action will take place until the overload on the remaining phase has existed for a predetermined period (10 to 15 secs.), thus allowing momentary overloads at starting, but providing adequate protection against an overload that would damage the windings. It will be noted that fuses, which can operate separately, when inserted in the conductors of a circuit feeding a three-phase motor, can actually be a source of danger to the motor should they fail to rupture simultaneously.

23. **Phase Reversal Protective Devices.**—Similarly, phase reversal protective devices are desirable for multi-phase alternating-current motor circuits. With a d.c. motor, either of the series or shunt type, no alteration in the direction of rotation occurs if the main conductors feeding the motor are reversed. Conversely, the direction of rotation of either a two- or a three-phase induction motor is reversed by changing over two of the main leads. Unless, therefore, phase reversal protection is included in the control gear, any repairs to the distributing system, either in the building or in the street, that accidentally resulted in two supply leads being changed over would cause the car to ascend when it was intended to descend, and vice versa.

CHAPTER XIII.

SHAFTS.

1. **Development.**—The enclosed vertical space, within which the lift car is arranged to run, is variously termed the shaft, hoistway, well, well-hole, hatchway, etc., the former probably being the term most commonly used in this country.

The primitive form of shaft consists merely of trap-doors or hatchways, formed in the various floors of a warehouse, vertically above one another, a chain or bar being used as a guard to prevent people falling down through the opening, should the trap-doors be left open. Later, the enclosures round the hatchways in the various floors were made of wood, and were only installed as a matter of convenience or comfort, as it was found that in cold weather, especially with doors open on the lower floors, the hatchways created a draught of air which caused much discomfort and also assisted to spread a fire when an outbreak occurred.

When passenger lifts were first installed, and, at the present time, when it is anticipated that one car will meet the traffic requirements, lifts are frequently located in the well formed in the centre of the open-newel type of staircase. In modern office and similar buildings where two or more passenger lifts are required, they are preferably grouped at or near the main entrance, and it is then standard practice completely to enclose them in a shaft of fireproof construction extending from the lowest landing right up to and through the roof.

2. **Staircase Wells.**—Should it be decided to install the lift in the well of an open-newel type of stair the enclosure is most frequently formed of ornamental wrought-iron grill or scroll-work or wire screens, which should be carried to a height of 7 ft., with an apron of the same material extending to the ceiling, opposite the door in the car (see Fig. 70).

The restrictions as to size of mesh or spaces discussed in detail in connection with cars apply almost with equal force to wrought-iron grill enclosures, the maximum space allowable

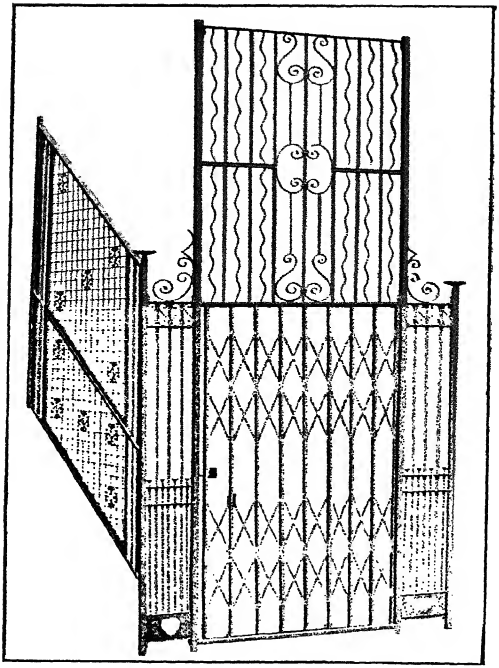


FIG. 70.—Wrought-iron lift enclosure for open well staircase, showing apron over entrance gate.

[*By the courtesy of the Express Lift Co., Ltd.*]

[*To face p.* 86.

being $1\frac{1}{2}$ in. between any two members except when straight bars are used, not filled with scroll, in which case the space should be reduced to 1 in.

Preferably, if at all possible, for staircase shafts it is desirable to arrange for the counterweight to run in a separate pocket formed in the outer walls of the staircase, as it cannot be considered a thing of beauty, nor can it be effectively camouflaged.

3. **Enclosed Shafts.**—Enclosed lift shaft construction may be very conveniently divided into two classes, i.e. (*a*) wood floor buildings, and (*b*) steel-frame or reinforced concrete buildings.

In wood floor buildings the shaft is practically a brick tube set on end, either in the interior of the building or just outside the wall, with doorways and entrances on each floor. When the fire risk must, of necessity, be minimised, the tube must be continuous from floor to roof, must be self-supporting, and must be built entirely within the hatchways formed in the various floors, i.e. no joists may protrude through the walls of the shaft but they may enter into and rest on it. If the shaft be formed of slabs, then, of course, the hatchways must be trimmed in a manner such that they are self-supporting. In both cases the hatchways in the floors must be made large enough to admit the brick or slab walls, and still leave the internal dimensions of the shaft of the size required.

When the floor construction is of a fireproof character there is no longer any need to carry the weight of the enclosure from the basement. All that is actually necessary is to form partitions on each floor, from floor to ceiling, either in brick, slab, or expanded metal and plaster, care being exercised to cover all exposed steelwork with plaster, concrete, etc., as required by the local by-laws.

Lift shafts are, according to circumstances, built in glazed brick, faced with glazed tiles, plastered, or merely left in brick and whitewashed or distempered. Black is a very satisfactory "*colour*" for unplastered brickwork, as the inequalities are not made as prominent as when whitewash is used.

4. **Overtravel Spaces.**—Overtravel spaces at both the top and the bottom of the shaft are essential, as the brake is subject to wear and cannot be relied upon for accurate floor levelling, especially with high-speed traction machines.

The depth of the pit or sump, i.e. the overtravel at the bottom of the shaft, should be 3 ft. 6 ins., measured from the lowest landing. For the higher speeds the space must be increased to 4 ft. 6 ins., and for traction type express lifts, 7 ft. 6 ins. may

be required. The writer had this point forcibly brought home to him on a recent trans-Atlantic trip, when, owing to the exigencies of space on the ship, every down trip finished in a most unpleasant bump, due to the fact that the overtravel space was limited to a few inches. As an additional precaution against jar or shock, should the brake slip, spring or oil buffers are used under the car and also under the counterweight. The cost of a spring-loaded set, of a simple character, is small, and the installation is strongly recommended.

A clear space of 3 ft. is usually the minimum required between the top of the crosshead of the car and the underside of the shaft ceiling when the car is at its top landing. For speeds above 350 ft. per minute, 5 ft. is regarded as the minimum space.

5. Footings, Pits, Steelwork Details, and Skylights.—All footings for columns and for foundations adjoining lift shafts should be carried below the pit in order to ensure that all sides of the pit are true and plumb with the finished sides of the shaft. Similarly, offsets on the inner sides of the shaft walls should be avoided wherever possible, since the working faces of both the car and counterbalance weight guide rails must be truly vertical, and any inaccuracy in the builders' work will involve considerable additional expenditure for erection of the lifts.

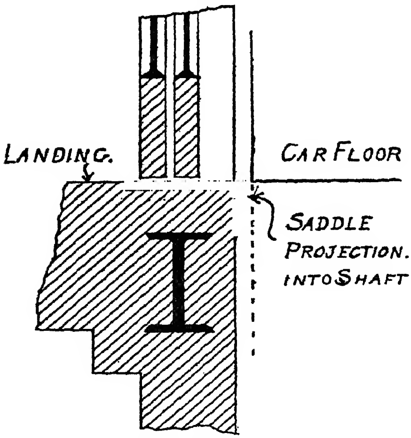


FIG. 71.—Floor saddle as projection. (Note flare or bevel.)

It is, of course, obvious that where the pits are near the water level or where there are underground springs, waterproofed pits are very necessary. A good layer of concrete is also required over the waterproofing to allow for rag bolts or other guide and buffer fixings, to avoid any risk of the lift erectors penetrating the waterproofing layer.

When the shaft is framed in steel, the greatest care must be exercised in preparing the special drawings in connection with the lifts, to show details of the amount of fireproofing required outside the flanges of beams, on the backs of channels, and on the columns; also the sizes of the beams or channels and the

relation of block partitions or walls to the inside of the finished shaft.

Projections into the shaft should be avoided wherever possible, but where absolutely unavoidable they should not be made sharp, but should be bevelled off at a slight angle (Fig. 71).

For enclosed lift shafts, American regulations also frequently call for glass skylights set in iron frames, to be fixed, having an area at least equal to three-fourths that of the shaft. Wire glass is usually prohibited, owing to the difficulty of the fire forcing its way through the skylight.

In buildings in which the shaft does not run down to the basement but terminates at an intermediate floor, the floor of the pit should be sufficiently strong to hold both the car and the counterweight in the event of failure of the ropes and safety gear.

6. **Overhead Gratings.**—For installations in which the engine is situated below the shaft, and overhead sheaves or wheels are necessary to lead the ropes to the car and to the counterbalance weights, American regulations and specifications almost invariably call for a substantial grating of iron or steel, to be fixed immediately below the overhead sheaves, having not more than $1\frac{1}{2}$ in. space between any two members. As the grating for overhaul and repair work will have to sustain the weight of several men, tools, etc., the rated loading is usually figured at 75 lbs. per sq. ft.; 2 in. pierced channels or $1\frac{1}{2}$ in. by $\frac{3}{8}$-in. flat bars with spool or corrugated bar separators being utilised to form it. Drip pans, constructed of 26 s.w.g. galvanised iron, should be provided for all bearings to prevent any oil dripping down the shaft and into or on to the car.

7. **Dimensions of Shaft.**—Strictly speaking, from the service point of view the size of the shaft should be determined after the car passenger capacity required has been calculated, but more frequently in practice the shaft size is probably first ascertained and a car is then designed to suit the shaft without reference to the traffic schedule. Assuming the correct method is adopted, the size of the car having been determined, the shaft dimensions will depend on the arrangement of the guides and counterbalance weight.

The majority of lift engineers will probably agree that the arrangement of steel side guide rails for the car with the counterweight running at the back of the car, also on steel guide rails, provides the most satisfactory scheme. There are many cases, however, where this design cannot be adopted, and, under these

circumstances, other schemes are frequently found to be necessary (Fig. 72).

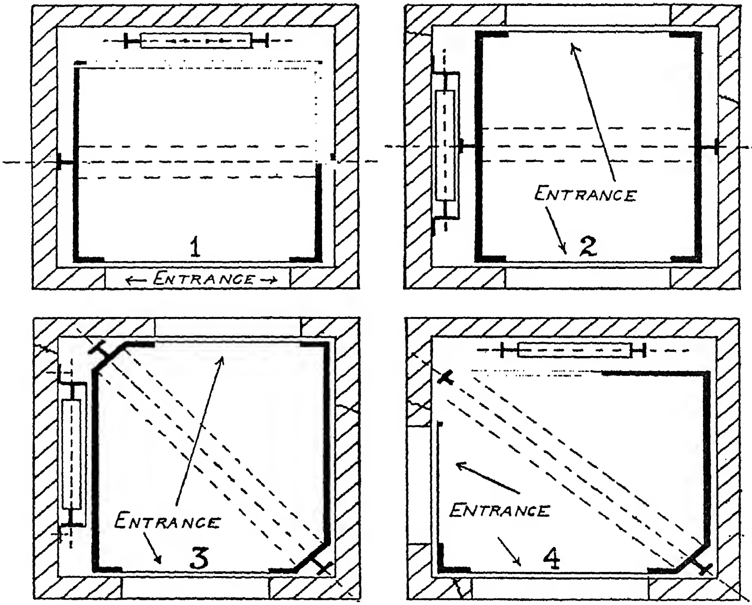


FIG. 72.—Arrangement of car guide rails and counterbalance weights.

(1) Car guide rails at side and counterbalance weight at back. (One entrance only.)
(2) Car guide rails and counterbalance weight at side. (Two entrances, i.e. straight through type.)
(3) Cross corner guide rails for car with counterbalance weight and side. (Two entrances, i.e. straight through type.)
(4) Cross corner guide rails for car with counterbalance weight at back. (Two entrances at right angles.)

TABLE XV.

CAR AND SHAFT DIMENSIONS (approximate only).

Scheme No.	1	2	3	4
Car width . . .	A-9 in.	A-14	A-9	A-4
Car depth . . .	B-9 in.	B-4	B-4	B-9

A = Width of shaft.
B = Depth of shaft (back to front).

Example.—Given shaft dimensions of 6 ft. wide by 5 ft. deep, car will be (6 ft. less 9 ins.) 5 ft. 3 ins. by (5 ft. less 9 ins.) 4 ft. 3 ins. for Scheme 1.

The figures given in Table XV. must be regarded as approximate only, as variations may be necessary when the engine is placed at the bottom of the well (requiring room for ropes), for excessively large balance weights, for large cars, and for special landing door and indicating gear.

The average thickness of the car wood or metal work is figured at about $1\frac{1}{2}$ in.

Many lift engineers consider it good practice to keep the front of the car $1\frac{1}{2}$ in. away from the entrance threshold, and to use saddle projections from $\frac{1}{2}$ to 1 in. beyond the finished line of the shaft at each landing. By this means it is possible to make good any unevenness in the shaft (a condition which is likely to occur during the course of the erection of the building), by plumbing the saddles and thus standardising the width of the space between the landing floor and the car threshold (Fig. 73). (In a recent case, on one of the author's jobs, a 60-ft. shaft was found to vary $2\frac{1}{2}$ in. from the plumb-line in two places !)

8. Dimensions of Engine Room and Load to be Carried.—One of the principal factors in the successful operation of lift equipment is the provision of ample accommodation for the overhead sheaves and for the engines.

The usual height of the car from the floor to the top of the cross-head is 10 ft., and allowing the overtravel space or head room of 3 ft., this indicates that the minimum height to the underside of the floor of the

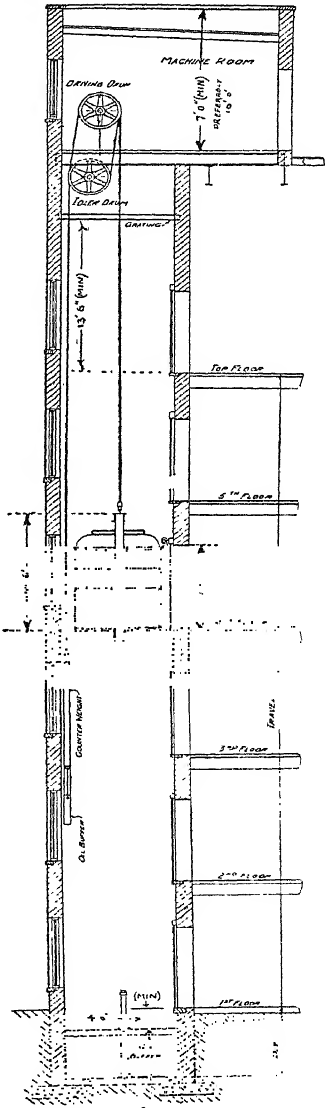


FIG. 73.—Landing saddles finished to plumb line.

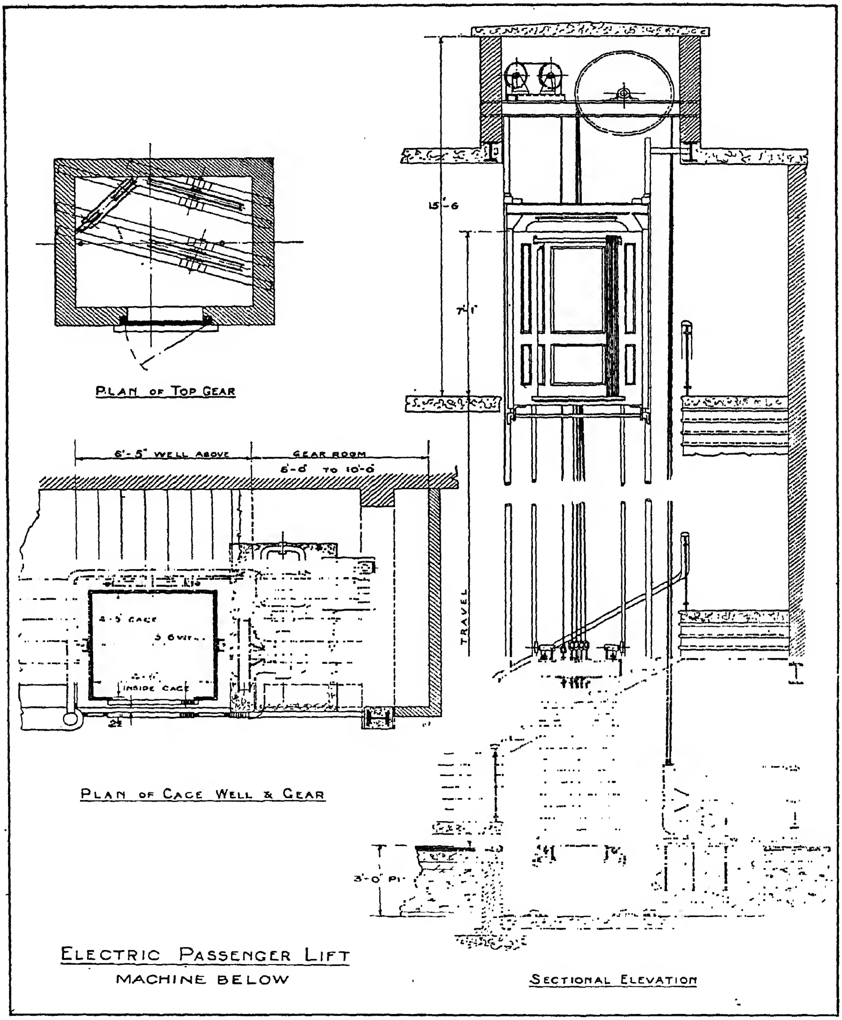


FIG. 74.—General arrangement of passenger lift equipment (engine below).
[*By the courtesy of Messrs. Waygood-Otis, Ltd.*]

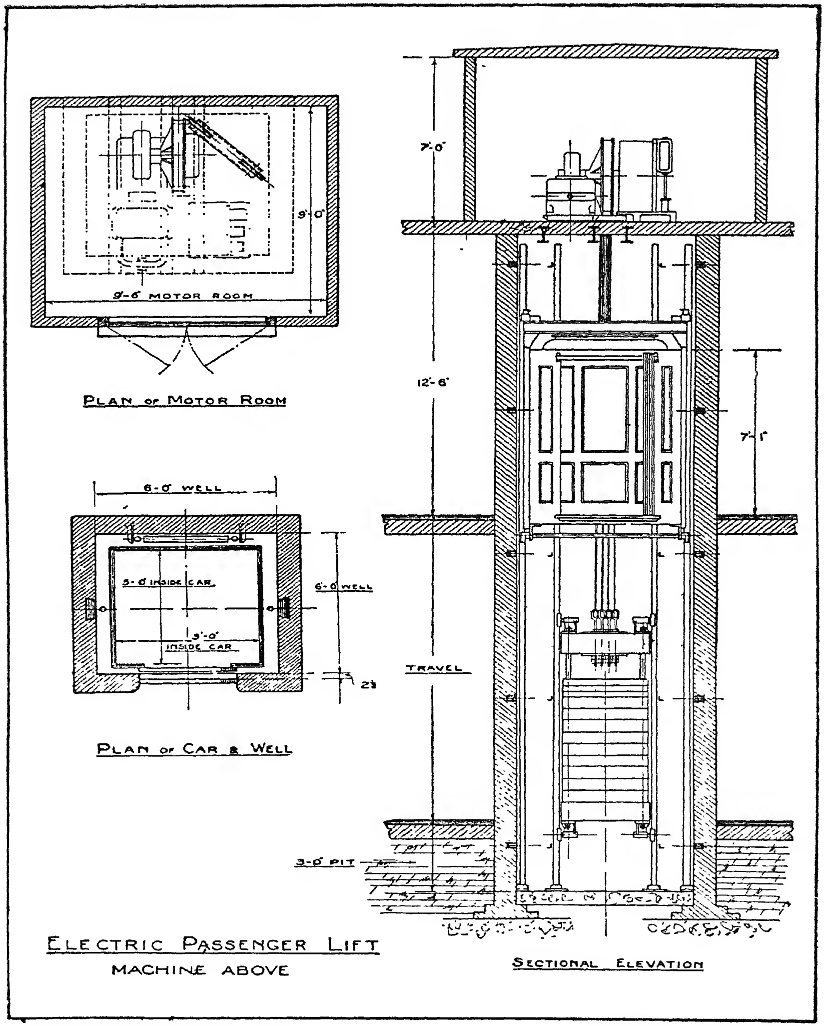


FIG. 75.—General arrangement of passenger lift equipment (engine overhead).
[*By the courtesy of Messrs. Waygood-Otis, Ltd.*]

engine or gear room from the top landing is 13 ft. The thickness of the floor depends upon the weight to be carried, but will not be less than 6 in. When the engine is in the basement, 4 ft. is probably sufficient, but 6 ft. is desirable for the guide sheaves at the top of the shaft. Seven feet clear height should be regarded as the minimum for the engine room, whether it be situated in the basement or at the top of the shaft, and 9 ft. 6 ins. is desirable for the larger machines. Wherever possible a steel joist and lifting tackle should be installed in the engine room to facilitate repairs when two or more lifts are provided (Figs. 74 and 75).

When the engine is at the top of the shaft, the rear wall of the engine house can usually be carried up flush with the rear wall of the shaft, but space about equal to the depth of the shaft (i.e. back to front) should be provided in front to accommodate the engine. The dead load on the engine room floor when the engine is located at the top of the shaft is, for a speed of 150 ft. per minute, very approximately as follows :—

TABLE XVI.

Load on Engine Room Floor.	
Car Capacity. Passengers.	Dead Load. Tons.
6	3
9	4
12	5
15	6
18	7

Reference should be made to the contractor for the actual figures relating to the equipment that it is proposed to install. In figuring the beams or floor to carry the engine the dead loads are usually doubled to allow for impact.

For an exhaustive study of this branch of lift engineering, reference should be made to *Elevator Shaft Construction* (H. R. Cullmer).

CHAPTER XIV.

LANDING DOORS.

1. General Considerations.—Very little attention has been devoted to the design of landing doors in this country, either the collapsible steel gate, the single, or the double folding door being almost exclusively used. These types, although more or less satisfactory, for single, slow-speed installations in low buildings, are excessive time wasters, and for high buildings, in which high speed, vertical transportation of passengers is of prime importance, new designs have been developed.

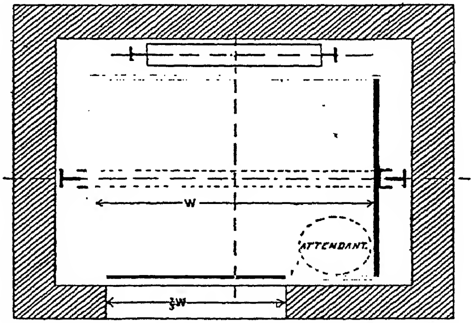


Fig. 76.—Width of car entrance and landing doorway.

In designing a lift shaft, careful consideration should be given to the size and type of door which is best adapted to the particular installation in view, a suitable width being provided to make loading and unloading as free as possible.

In locating landing doors, consideration should be paid to the desirability of arranging for the car attendant to handle the car controller with his *left* hand and open and close the doors with his *right* hand, the doors sliding from right to left to open.

The landing door should be as light in weight as possible and be placed as close as possible to the shaft, so that there is no necessity for the operator to leave the controller in order to operate the door.

The minimum width of opening is usually regarded as 2 ft. 6 ins. and the standard height as 7 ft. Mr. R. P. Bolton, in *Elevator Service*, emphasises the desirability of definitely

providing a space in the car for the attendant or operator, and therefore recommends that the landing and car doors should be two-thirds the width of the car. This proposal apparently conflicts with the recommendation made above for free ingress and egress, but since the operator should not waste time in leaving the car at the landing and would therefore obstruct the entrance in any case, the advantages, it is thought, outweigh the disadvantages (Fig. 76).

The principal types of landing doors for modern passenger lifts are shown in Fig. 77.

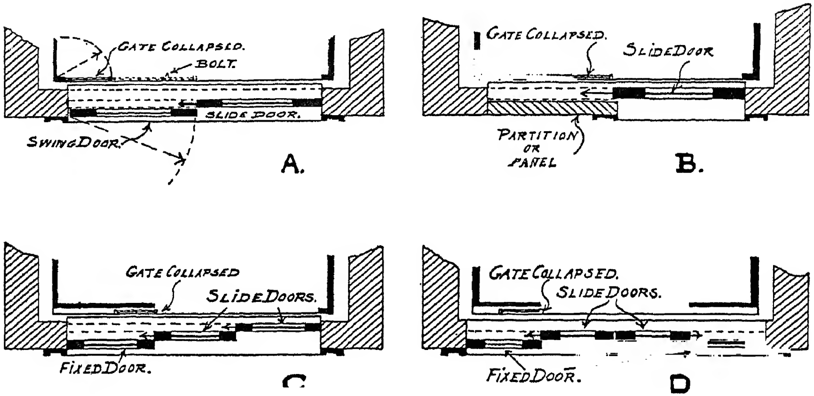


FIG. 77.—Arrangement of modern landing doors.

A, Combination slide and swing door. B, Single slide door. C, Double doors sliding in the same direction. D, Double doors sliding in opposite directions.

Doors of the types illustrated have the advantage over single and double swing doors ordinarily used in England, that air pressure (caused by a high-speed car moving in a closed shaft) has no tendency to open them, should the latch be insecurely fastened.

2. Combination Slide and Swing Doors.—The combination slide and swing is useful in flats and office buildings, since it is specially adapted to both passenger and goods service. Normally only the sliding door is used, but, should packing-cases, safes, trunks, etc., have to be handled, then the swing door in addition to the sliding door can also be opened. In this case the top steel rail which carries the sliding door, would be fixed to the swinging door, and arrangements would have to be made whereby the

pins of the sliding door, which engage in the floor groove, could be thrown out of action when the swing door is opened (Figs. 77 A and 80).

3. Single Slide Doors.—Single slide doors are, of course, cheaper than the combination slide and swing door, and are suitable for narrow cars used exclusively for passenger services. The left-hand section can either be made a stationary panel, or a partition can be built up in place of the stationary doors or panels (Fig. 77 B and 79). The door is usually $1\frac{1}{2}$ in. thick and there is a $\frac{1}{4}$ in. clearance between the door and the stationary panel or partition. Twelve inches should be provided above the door to take the steel rail and wheels. The grooves in the sills should be $\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. deep, for with these allowances it is practically impossible for a door to jump the grooves.

4. Double Doors Sliding in the Same Direction.—Double doors, sliding in the same direction, are possibly the best form for general use where the necessary space can be obtained. Very careful consideration must be given to this type, in designing the landing doorways, as space must be provided for two doors, and the fixed partition or panel, plus the clearance spaces required between the first and second doors, and the second door and the fixed panel or partition (Fig. 77 C and 81).

Devices are now available whereby the one door travels at twice the speed of the other, so that both will be fully open or shut together. The space and clearances required are similar to those given for single slide doors.

5. Double Doors Sliding in Opposite Directions.—Double doors, sliding in opposite directions, are regarded as more symmetrical in appearance and operation, but further restrict the ingress and egress to the car. They are, therefore, not so popular for high-speed work, but require less space than the double doors sliding in the same direction. Both doors should be mechanically interconnected so that they both move the same distance, either in opening or closing by the operation of either door. It is desirable to design the doors and the panels, if space permits, so that the fixed panels are at least equal to, and preferably greater in width than, the doors which slide behind them (Fig. 77 D and 78).

Needless to say, for efficient service, the hardware used on the doors should be as accessible and as free in operation as possible. Inaccessible and stiff door fastenings will cause serious delay during the course of a day. If desired, sliding doors can be made self-closing by fixing the running rails slightly out of

the horizontal. In any case, rubber bumpers should be provided at the top and at the bottom of the doors to take the jar both in opening and closing.

6. **Door Lights.**—U.S.A. regulations specify that when lights are required in landing doors, wire glass *must* be used, the area of any one pane being restricted to 5 ft. super.

7. **Door Operating Devices.**—Pneumatic door operating devices can be fitted to any type of landing door, where funds are available, but additional space is required and details should be carefully investigated where it is decided to adopt them. The pressure usually adopted is 25 lbs. per sq. in., and electrically operated compressors are necessary. Specifications usually call for the operating devices to be of the non-adjustable type, without packing glands, and to be arranged to cushion the doors on both the opening and closing motions.

8. **Architectural Treatment.**—The treatment of the doors or gates usually falls outside the engineer's province and these details are not therefore discussed, but attention is directed to the desirability of providing glazed panels to avoid accidents and of considering the question of signalling devices, direction indicators, etc., at an early date and incorporating them in the design. These items of equipment will be described later (Figs. 78, 79, 80, and 81).

9. **Automatic Fire Doors.**—Automatic fire doors or similar devices that cover the shaft openings in the event of fire should not be installed, as they prevent the lift being used as a means of escape.

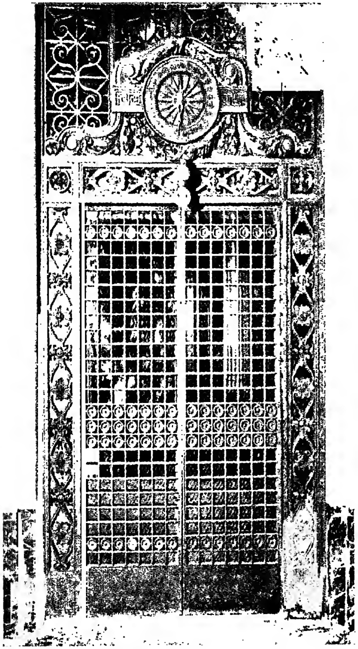


FIG. 78.—Double doors, sliding in opposite directions, made in ornamental iron and backed with wired glass. Note dial indicator. Messrs. D. H. Burnham & Co., Architects. Reprinted from *Elevator Shaft Construction* (Cullmer).

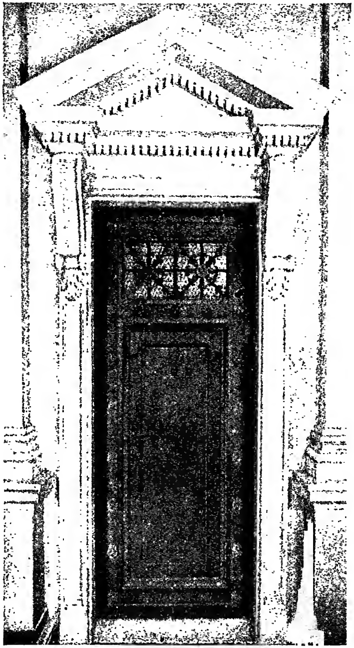


FIG. 79.—Single slide door in bronze. Messrs. N. Le Brun & Sons, Architects. Reprinted from *Elevator Shaft Construction* (Cullmer).

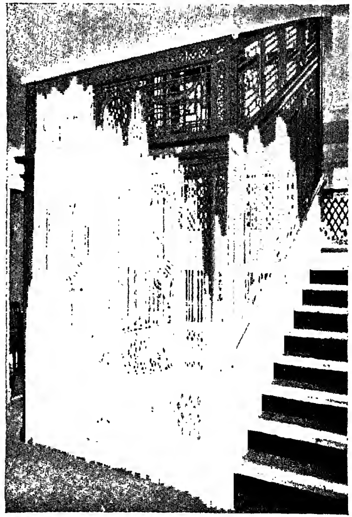


FIG. 80.—Combination slide and swing doors in grille work for an open stair well. Messrs. Delano & Aldrich, Architects. Reprinted from *Elevator Shaft Construction* (Cullmer).

[*To face p.* 98.

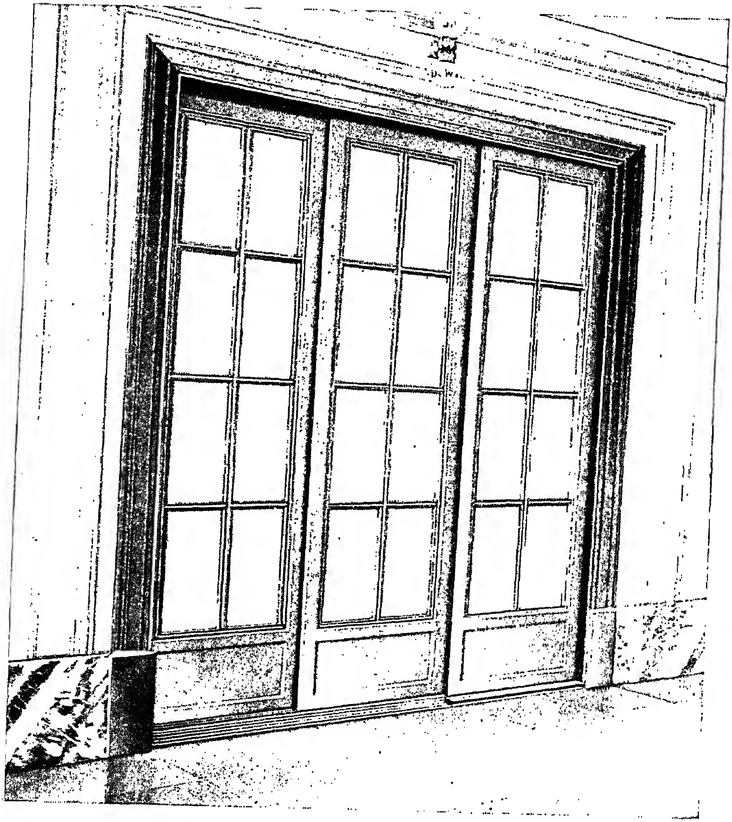


FIG. 81.—Double doors sliding in the same direction.
[By the courtesy of Messrs. Waygood-Otis, Ltd.]

[See p. 98.

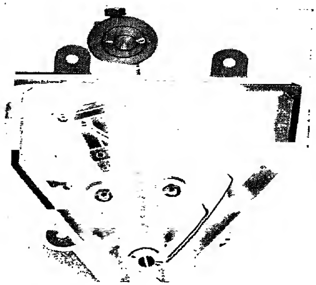


FIG. 82.—Terminal limit switch (self setting).
[*By the courtesy of Messrs. R. A. Evans, Ltd.*]

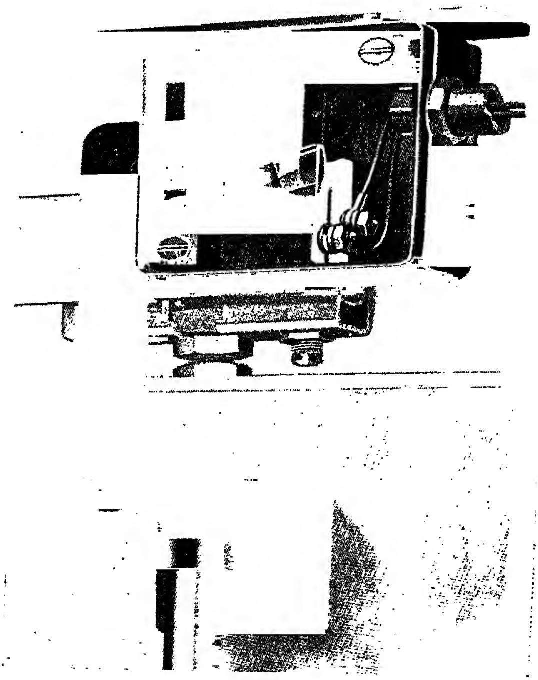


FIG. 83.—Electro-mechanical interlock for sliding doors.
[*By the courtesy of the Elevator Supply Repair Co.*]

[*See p.* 101.
[*To face p.* 99.

CHAPTER XV.

SAFETY AND PROTECTIVE DEVICES.

1. The Principal Safety and Protective Devices.—The principal safety and protective devices employed in connection with lifts are as follows :—

(*a*) Guide grips and overspeed governors (discussed previously in Chapter IV.).
(*b*) Car safety switch.
(*c*) Terminal limit switches.
(*d*) Overtravel limit switches.
(*e*) Slack cable switch (drum drive only).
(*f*) Door and gate safety switches and locks.
(*g*) Compensating cable switch.
(*h*) Buffers and air cushions.
(*i*) Phase failure protective relay } a.c. motors only.
(*j*) Phase reversal protective relay } a.c. motors only.

2. Car Safety Switch. — The car safety switch is more usually seen in American than in English lift cars. It consists merely of a single pole switch connected in a cable of the opposite polarity to that connected to the car switch, so that in the event of the failure of the latter, due to earths, short circuits, mechanical damage, etc., the car can be stopped by operating the car safety switch.

3. Terminal Limit Switches. — Terminal limit switches, which are usually self-setting,[1] are located at the upper and the lower landings, and are employed for the purpose of bringing the car to rest should the attendant be negligent in this respect. They may be mounted on the car and operated by cams in the shaft, or vice versa (Fig. 82). Another method is to extend the spindle of the car switch handle through the side of the car and to fix a lever to it. When the car is approaching either of the

[1] By the term self-setting it is understood that the car can be backed out or operated in the reverse direction. Immediately the car moves away, a spring restores the switch to the "On" position.

extremes of travel, the lever engages with a cam suitably located in the shaft, and this forces the car switch into the "Stop" position, thus bringing the car to rest.

On drum type winding engines, these terminal limit switches may be geared to the winding engine, since the ropes are made fast to the drum, and certain positions of the drum definitely correspond to floor levels.

4. **Overtravel or Ultimate Limit Switches.**—Ultimate or overtravel limit switches are almost invariably fixed in the shaft, and are usually connected on the main circuit, so that when they operate all current is definitely and immediately cut off from the motor without the intermediate action of any magnet-operated or other switches. They are operated by cams fixed on the car, are placed beyond the normal range of travel, and are employed to stop the car should the attendant forget to operate the car switch and the terminal limit switch fails—a dual combination of negligence and accident.

As such an event is undoubtedly serious, it is desirable deliberately to arrange the connections in a manner such that the car cannot be backed out or operated in the reverse direction merely by working the car switch. By this arrangement the attention of a responsible person is drawn to the incident, and he should see that the cause of overrunning is attended to before again putting the lift into service.

It is clearly undesirable to operate ultimate limit switches by pilot ropes or by other indirect methods which may be out of order at the only time when they are called upon to act.

5. **Slack Cable Switches.**—Slack cable switches are chiefly fitted to drum machines, and function in the event of the car or the counterweight becoming stalled or held up in the shaft. They operate immediately the cables slacken. In the absence of this safety device in the circumstances mentioned the ropes would continue to unwind, and should the cause of stalling be of a temporary nature and the car release itself, it would immediately fall to the full extent of the cable unless the car safety gear operated.

6. **Door and Gate Safety Locks and Switches.** — *Protection of Hoists*, issued by the Home Office, London, states :—

> A large number of hoist accidents are caused by crushes between the travelling cage and the door lintels or other projections in the hoist well. Practically the whole of these would be prevented by fitting a collapsible gate on the cage itself, but to ensure that the gate is used *it must be provided with interlocking mechanism* which requires the gate to be closed before the cage can be started. . . . In addition to the gates on the cage itself, each doorway should

be provided with a gate or door, fitted flush to the inside of the well, so constructed that (1) it cannot be opened until *the cage is at rest* opposite to that floor or landing; and (2) that the cage cannot be moved away until the door or gate is closed and fastened.

Statistics collected by the U.S.A. Bureau of Standards show that 73·8 per cent. of all fatal accidents in that country might be prevented by well-designed interlocks fixed to landing doors. (See Appendix.)

All forms of landing door protective devices may be broadly classified into three divisions, according to the method of locking the car and the landing door, i.e. :—

(*a*) The mechanical type.
(*b*) The electro-mechanical type.
(*c*) Electrical contact devices.

The first type of safety lock depends upon mechanical action to lock the car control mechanism while the door is open, and to hold the door in the locked position when the car is not at the landing. Substantial latches, or rotating bars, are frequently employed for locking the door, in conjunction with slotted flaps or stirrups, operated by bolts or rods, to lock the car switch in the neutral position. Parts of the device which are located within the car should be enclosed to avoid risk of interference which might render them inoperative.

Briefly summarised, the functions of the mechanical type of interlock are: (*a*) to release the landing door, (*b*) to lock the control mechanism, (*c*) to release the control mechanism, (*d*) to lock the landing door.

Electro-mechanical interlocking devices are more popular than the purely mechanical types, and can be entirely relied upon to prevent shaft-door accidents if of sound design and manufacture and adequately maintained. In this type the door is mechanically held closed and the car is interlocked by some form of electrical control. This may be accomplished either by interrupting the master or control circuit, or by running an independent circuit that will interrupt the operating current on the motor control board. An essential feature of this type of control is that the electrical contact should be made *after* the door is mechanically locked, and, if possible, the design should be such that failure of the door to lock should render the electrical contact inoperative (Fig. 83). Otherwise the car would be able to move away, leaving the door unlocked.

The third class of door safety devices comprises a wide variety

of electrical landing door and gate contacts that are usually connected in series in the control circuit and are known as the shaft series system. The difference between this class of safety device and the electromechanical interlock should be carefully noted. The contact device merely prevents the car being moved until all landing doors are closed, but it is possible to open any door with the car in any position in the shaft, although of course the car, if in motion, would automatically be brought to rest (Fig. 84).

Ordinary latches, operated from the car side, are occasionally used to hold the landing doors closed, but the attendant or passenger must then be relied upon to operate the latch. A survey made by the U.S.A. Bureau of Standards of several hundreds of landing doors, indicated that 30 per cent. of the latches were out of order, due chiefly to worn latch parts, worn door hangars, loosening of latch from door, and lack of lubrication. It was also found that many latches were so poorly designed that if the door were closed quickly the rebound of the door would occur before the latch engaged.

When electrical interlocks are provided it is not unusual to locate an emergency switch or release device in the car so that in the event of fire, panic, or other emergency, or if the car stops in the shaft due to the failure of the door safety circuit, the operation of the emergency device will permit the lift to continue in operation. Such a device, if provided, should obviously be of the spring or push-button type that must be held in the emergency position by the attendant, and should be enclosed in a glazed case.

Commenting on the results of the survey,[1] the authors state that out of the hundreds of elevators inspected none were equipped with a mechanical interlock in which the four vital functions of unlocking the landing door, locking the car control mechanism, unlocking the car control mechanism, and locking the door, were performed by means of positive mechanical motion. In other words, at least one, and generally more, of these functions are accomplished by means of gravity or by springs or by a combination of the two.

Attention is also directed to the fact that door contacts are seldom rugged enough to stand up under the impact and vibration of the landing door, where they are actuated by the impact of the door itself. Further, it was found that in nearly

[1] *Elevator Interlock Report*, U.S.A. Bureau of Standards.

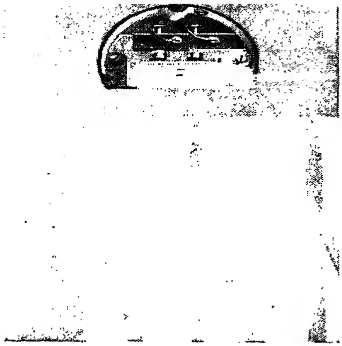


Fig. 84.—Electric door or gate contact.
[*By the courtesy of Messrs. R. A. Evans & Co.*]

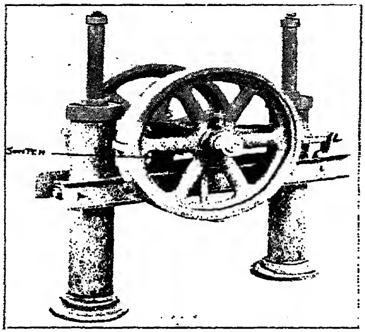


Fig. 85.—Compensating cable sheaves and switch.

[*See p.* 104.

[*To face p.* 102.

every case the making and breaking of the current was dependent directly upon and was accomplished at the same speed as the opening and closing of the door. Many such devices, if the door fails to latch, are left in but slight contact and may produce an arc that will rapidly destroy the contact surfaces. The authors very rightly observe that a sequence coil or a quick make and break switch will do much to eliminate such arcing and pitting.

Definitions and Specifications relating to Landing Door Interlocks, Landing Door Controls, and Emergency Releases, which it is understood were formulated by the U.S.A. Bureau of Standards and which are stated to agree in all essentials with those tentatively adopted by the Joint Committee appointed to formulate a national code for the American Society of Mechanical Engineers, are extracted from the *Elevator Interlock Report*, dated March 14, 1921, and given below:—

1. Definitions.

Hoistway-door Interlock.—A hoistway-door interlock is a device the purpose of which is—

1. To prevent the normal operation of the car, except by the use of a levelling device, unless (*a*) (door unit system) the hoistway door opposite which the car is standing is locked in the closed position; or (*b*) (hoistway unit system) every hoistway door is locked in the closed position.

A hoistway door or gate shall be considered locked in the closed position when within 4 ins. of the full closure. If in this position, and any other up to full closure, the door or gate cannot be opened from the landing side more than 4 ins.

Interlocks which permit the starting of the car before the door is fully closed shall be so equipped that except when the door is locked in the position of full closure the door or gate can be opened from the landing side to the position approximately 4 ins. from full closure.

2. To prevent the opening of a hoistway door (except by use of a key) from the landing side when the car is passing a landing; except when the car-control mechanism is in the "stop" position.

Hoistway-door Electric Contact.—A hoistway-door electric contact is an electrical device the purpose of which is to prevent the normal operation of the car except by the use of a levelling device unless (*a*) (door unit system) the hoistway door opposite which the car is standing is in the closed position, or (*b*) (hoistway unit system) every hoistway door is in the closed position.

Emergency Release.—An emergency release is a device the purpose of which is to make hoistway-door electric contacts or hoistway-door interlocks inoperative.

2. Specifications.

Hoistway-door Interlock Specifications.—(*a*) The prevention of the operation of the car by a hoistway-door interlock shall not be dependent on the action of springs in tension nor solely upon the completion or maintenance of one electrical circuit.

(*b*) The agency used to perform any interlocking function shall be such that even without lubrication of the mechanism the intended functioning of the device will be completely performed.

(*c*) The locking of the hoistway door and the interlocking of the car control shall be accomplished by an interconnection between the parts of the device. This interconnection may be mechanical, electrical, hydraulic, or pneumatic.

(*d*) It shall be necessary to accomplish the locking of the hoistway door opposite which the car is standing before the car can be moved by normal operation.

This paragraph applies to both the door unit and the hoistway unit system.

(*e*) If without damage to, removal of, or interference with any part of the elevator or hoistway equipment the door opposite which the car is standing becomes unlocked, it shall be impossible to start the car by normal operation.

HOISTWAY-DOOR ELECTRIC CONTACT SPECIFICATIONS.—(*a*) The prevention of the operation of the car by an electric contact shall not be dependent on the action of springs in tension nor solely upon the completion or maintenance of one electric circuit. The failure of the device shall manifest itself by preventing the starting of the elevator from the landing.

(*b*) The device shall be such that without lubrication of the mechanism the intended functioning will be completely performed.

(*c*) All live parts shall be inclosed.

EMERGENCY RELEASE.—(*a*) The emergency release shall be in the elevator car, plainly visible to the occupants and reasonably, but not easily, accessible to the operator.

(*b*) To operate under emergency conditions, it shall be necessary for the operator to hold the emergency release in the emergency position. The emergency release shall be so constructed and installed that it cannot be readily tampered with or "plugged" in the emergency position.

(*c*) Rods, connections, and wiring used in the operation of the emergency release that are accessible from the car shall be inclosed to prevent their being tampered with readily.

WASHINGTON, May 14, 1921.

Tables comparing the functions and maintenance of various types of lift door devices and comparing the service of hoistway-door interlocking devices for various classes of buildings are also reprinted, as it is considered that the data given therein will be extremely valuable to lift engineers and to architects.

7. Compensating Cable Switch.—For lifts installed in high buildings, on which compensating cables are fitted, a compensating cable switch may be provided and connected so that it is opened by the raising or lowering of the compensating cable sheaves in the pit. The switch interrupts the control circuit should the sheaves lower to any appreciable extent due to cable stretch. Also, in the event of the counterweight or car becoming stalled in the shaft, the compensating cable sheave will rise and operate the switch to cut off the power (Fig. 85).

8. Car and Counterweight Buffers.—Buffers are desirable under the car and under the counterweight. For low speeds, a spring alone is used, but for higher speeds a combination of oil dash-pots and spring is necessary. They should provide a retarding effect so that the maximum retardation will not exceed 64·4 ft.

Comparison of Functions and Maintenance of Various Types of Elevator Door Device, Elevator Interlock Report, U.S.A. Bureau of Standards.

Mechanical.	Electro-mechanical.		Electric Contacts.
	Undercar-contact Type.	Hoistway-contact Type.	
Locks door and prevents operation of car if door is unlatched or unlocked.	Locks door and prevents operation of car if door is unlatched or unlocked.	Locks door and prevents operation of car if door is unlatched or unlocked.	Does not lock door and does not prevent operation of car if door is unlatched.
Interlocks car when door is open . .	Interlocks car when door is open . . .	Interlocks car when door is open . . .	Interlocks car when door is open.
Slows down service slightly . . .	Slows down service slightly	Slows down service very slightly . . .	Slows down service very slightly.
Usually designed to prevent opening of shaftway door with key unless car is at the landing.	Usually designed to prevent opening of shaftway door with key unless car is at the landing.	May or may not prevent opening of door with key unless car is at the landing, depending on design.	Door may be opened with key when car is not at landing.
Failure of mechanical parts on one door does not affect protection of other doors.	Failure of electric contact will eliminate interlocking of car, but will not affect the mechanical locking of shaftway doors (partial protection until repairs are made).	Failure of electric contact will eliminate interlocking of car, but will not affect the mechanical locking of shaftway doors (partial protection until repairs are made).	Failure of device at one door necessitates running the entire door system without the interlocking protection until repairs are made. Doors may or may not be latched, depending on condition of door latch.
Prevents opening of door by operator unless car is within a few inches of the landing.	Prevents opening of door by operator unless car is within a few inches of the landing.	Door can be opened when operator is in position to reach door-opening device.	Door can be opened when operator is in position to reach door-opening device.
MAINTENANCE AND OPERATION.			
Renewals infrequent	Renewals not frequent	Renewals not frequent	Renewals frequent.
Necessary to use emergency release very occasionally.	Necessary to use emergency release very occasionally.	Necessary to use emergency release occasionally if switch is not subject to door impact; much oftener if switch is subject to such forces.	Necessary to use emergency release fairly often if switch is subject to door impact and vibration, otherwise much less often.
Danger of crushing passengers slight, as doors must be closed and locked before car starts.	Danger of crushing passengers slight, as doors must be closed and locked before car starts. Short-circuit, ground, or an emergency switch thrown may set up a very dangerous crushing hazard.	If contact is not made until door is shut, crushing hazard is slight. If contact is made before door reaches full closure, the entering passenger may be caught and crushed by the starting car. Short-circuit, ground, or an emergency switch thrown may set up a very dangerous crushing hazard.	If contact is not made until door is shut, crushing hazard is slight. If contact is made before door reaches full closure, the entering passenger may be caught and crushed by the starting car. Short-circuit, ground, or an emergency switch thrown may set up a very dangerous crushing hazard.

Comparison of Service of Hoistway-door Interlocking Devices for Various Classes of Buildings, Elevator Interlock Report, U.S.A. Bureau of Standards.

Buildings in which the volume of traffic is heavy, and for which there is a special elevator maintenance and inspection service, e.g. large office buildings, first-class hotels, high-grade flats or apartment houses, large railroad terminals or stations, municipal or state buildings in cities, and large department stores.

Mechanical.	Electro-mechanical.	Electric Contact.
Parts fail through wear due to heavy service.	Parts fail through wear and arcing due to heavy service.	Parts fail by wear and arcing due to heavy service and where the switch is actuated directly by the door, by mechanical breakdown due to door impact and vibration.
Buildings in which the traffic is heavy but in which no regular maintenance or inspection service is provided, e.g. small office buildings in large cities, large office buildings in small cities, lofty and manufacturing buildings, small hotels in cities, medium size apartment houses, small department and other stores in cities.		
Fail through rapid wear and mechanical breakdown due to lack of proper lubrication and lack of alignment combined with severe conditions of service.	Fail through mechanical or electrical breakdown due to lack of proper lubrication, lack of alignment, dirt and grit on contact surfaces combined with severe service conditions.	Fail through mechanical and electrical breakdown due to dirt and grit on contact surfaces, lack of proper lubrication combined with severe service conditions and where the switch is actuated directly by the door, to breakdown due to impact of door, vibration, lack of alignment between door and switch.
Buildings in which the service is light and in which the equipment receives but little care and attention, e.g. small office buildings in towns or small cities, storage or warehouse buildings, small hotels, manufacturing plants where the upper floors are used largely for storage, and small shops and retail stores where most of the selling is done on the ground floor.		
Fail through mechanical wear augmented by lack of proper lubrication.	Fail through mechanical wear or failure of contacts due to oxidation, corrosion, or pitting due to infrequent use and dirt on contact surfaces.	Fail through oxidation, corrosion, and pitting of contact due to infrequent use and dirt on contact surfaces.

per second. Air cushions, obtained by forming a practically air-tight shaft at the lower end for a certain percentage of the total height, have been used for the purpose of retarding the motion of a falling car, but have been practically abandoned as unnecessary to safety.

9. Phase Failure and Reversal Protective Devices.—See pages 84 and 85, pars. 22 and 23.

CHAPTER XVI.

METHODS OF OPERATING LIFTS, SIGNALLING SYSTEMS, AND TRAVEL RECORDERS.

1. Considerations to be Observed in Selecting a Signalling System.—Signalling devices frequently receive scant consideration, although they form one of the links in the chain of modern elevator equipment, and failure of any link in a chain renders it, as a rule, more or less useless for its intended purpose. Continuing the analogy, just as a dog chain would be unsuitable for lifting a ship's anchor, so a signalling device which could be applied, with every prospect of success, to a single slow-speed lift, would be a failure if installed in connection with a group of high-speed lifts running to schedule in a modern office building.

Apart altogether from the effect, beneficial or otherwise, of a particular signalling system on the efficiency of the service to the tenants, it will, if properly designed, ensure minimum cost of operation by eliminating unnecessary travel and landing calls, and reducing the cost of power and wear on the working parts to a minimum.

The chief points to be considered when selecting signalling equipment for a modern installation of lifts are the number of cars in one group, their speed and location with reference to other cars or groups of cars, the purpose for which they are to be used, and their method of operation, i.e. on call, or running to schedule.

2. "On Call" System of Operation.—Cars operated on the "On Call" system remain at the ground floor until a call is received, then one car answers the call and carries the passenger to his or her destination. Such a method of operation is suitable for installations up to three cars, located in institutional buildings, hospitals, municipal buildings, small hotels, and office buildings, etc.

3. Schedule System of Operation.—Where three or more lifts are installed in a group in large office buildings, stores, hotels, etc., the schedule system of operation is usually found to be more economical. This is the tube or tram system of operation applied to vertical transportation, since the cars run from the bottom to

FIG. 86.—Operator's signal light.
[*By the courtesy of the Elevator Supply and Repair Co.*]

FIG. 87.—"Up" and "Down" passenger signal lantern.
[*By the courtesy of the Elevator Supply and Repair Co.*]

[*To face p.* 109.

the top of the shaft and return to the bottom again in continuous rotation, irrespective of the calls received from the upper floors or the passengers to be carried from the ground floor.

4. **Essentials of a Signalling Equipment.**—In large office buildings, the ideal signal system should notify the operator of the first approaching car in which direction the passenger desires to travel, and the floor at which the passenger is waiting, and this notice should be given in a decisive manner, without taking the operator's attention from his duties. It should also tell the waiting passenger which of the several cars will arrive first, and give him ample time to get to the proper landing door, thus avoiding delaying the car when it arrives.

Lamps are more popular than bells or buzzers for calling the attention of both the passenger and the operator, as they are noiseless, and are local rather than general.

5. **Complete Flashlight Signal.**—A signalling equipment, suitable for the types of building mentioned, is known as the Complete Flashlight System. It provides an operator's signal light in each car (Fig. 86); an "Up" and "Down" passenger signal lantern placed over each landing door (Fig. 87) in plain view of the waiting passenger; and an "Up-Down" push-button box conveniently located in the corridor at each floor. The operator is signalled by the flash of one lamp, which he can see, whether or not he is looking in that direction. Similarly, the waiting passenger is signalled by the flash of one lamp that immediately attracts his attention and directs him to the landing door at which the car will stop.

The controlling mechanism, which is located in the engine-room, is designed to accomplish the following results on the pressure of the "Up" or "Down" landing button by the waiting passenger:—

(*a*) Notify the attendant of the nearest car travelling in the required direction, when his car is within one-and-a-half floors of the landing at which the passenger is waiting.

(*b*) Illuminate the landing lantern corresponding to that car, three floors in advance of the car's arrival.

(*c*) Extinguish both car and landing signal lamps when the call has been replied to by the arrival of the car.

In each car a transfer switch, or button, is provided so that, should the nearest car be full, the operator can transfer the call to the next approaching car, and thus relieve the passenger of the necessity of pushing the button again after the first car has passed.

6. Operator's Signal.—A cheaper type is the Operator's Signal. It is similar in character to that described above except that the landing lanterns are omitted, i.e. it notifies the car attendant when to stop, but the waiting passenger is not instructed at which door to wait for the car. This modification would be suitable for a group of not more than four lifts in which the doors are relatively close together.

7. Department Store Signal.—Lift cars in large stores are frequently operated on the local schedule system, i.e. each car stops at each floor, both on the up and on the down trip, so that landing door call buttons are not required. Waiting passengers must, however, be notified at which door to wait, and an "Up" and "Down" signal lantern is therefore required over each landing door on each floor, i.e. for a group of six lifts serving six floors in addition to the ground floor, thirty-six double "Up" and "Down" signal lanterns would be required.

8. Flashlight Annunciator Signal.—For hotels, clubs, flats, and similar buildings, in which the traffic does not call for a regular schedule, or for any car invariably to make the complete trip, the Flashlight Annunciator System is frequently found to meet all requirements. The equipment installed in connection with this system includes one "Up" and "Down" push-button box at each floor, the necessary controlling devices in the engine-room, and a signal panel or annunciator box fixed in each car. This box contains two vertical rows of miniature lamp indicators, numbered to correspond to the landings and coloured, one red and the other white, representing the "Up" and "Down" signals respectively (Fig. 88). As the lamps are small, a buzzer is frequently connected in circuit to give an audible warning to the operator that a call has been registered.

A call from any landing is signalled in all cars simultaneously by the illumination of the appropriate lamp indicating the landing from, and the direction in which the waiting passenger desires to travel. The lamps in all cars remain illuminated until one of the cars answers the call, whereupon all lamps are automatically extinguished by the controlling mechanism. In lieu of lamps, indicators of the type commonly used in connection with electric bell installations may be employed, and fixed in the cars, the automatic clearing feature being still retained.

9. Electric Bell and Indicator.—For single car installations the straight electric bell, with pendulum or mechanical replacement indicator, forms the cheapest system of signalling, and is largely employed in this country. In this case push buttons are

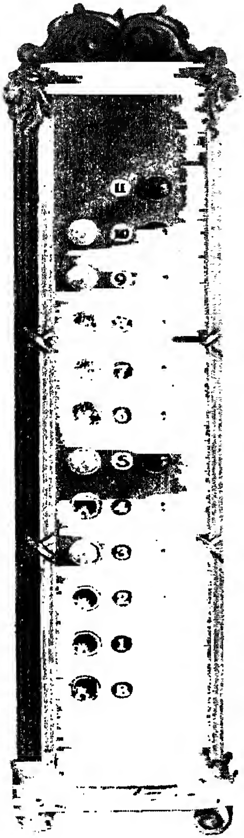


FIG. 88. -Operator's flashlight annunciator.
[*By the courtesy of the Elevator Supply and Repair Co.*]

[*To face p.* 110.

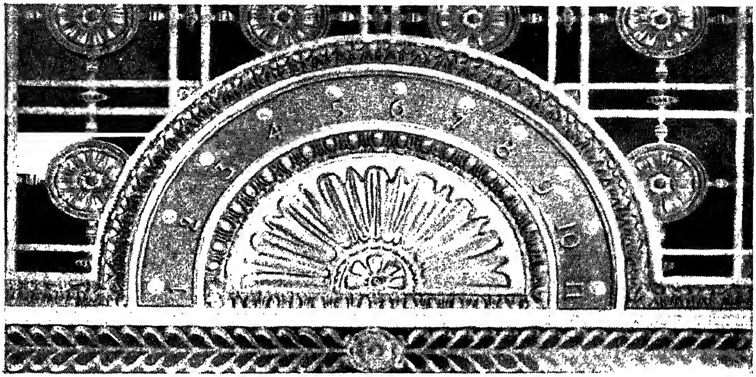


FIG. 89.—Electrically operated car position indicator.
[*By the courtesy of the Elevator Supply and Repair Co.*]

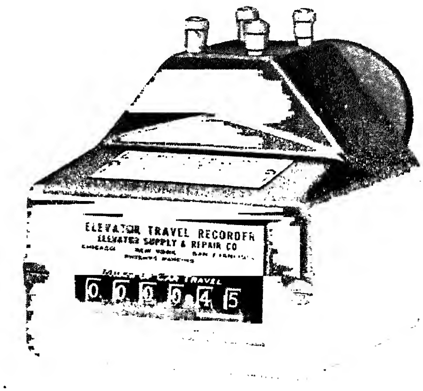


FIG. 90.—Car travel recorder.
[*By the courtesy of the Elevator Supply and Repair Co.*]

[*See p.* 112.

[*To face p.* 111.

fixed at each landing door, and the indicator is located in the car. The indicator should preferably be fitted with two rows of flags, and "Up" and "Down" push buttons should be fixed at the landing doors, since time is lost if the car stops on the "Down" trip in response to a call from a passenger who desires to travel in the upward direction, and vice versa.

10. Car Position Indicator.—Car position indicators are of two main types, i.e. :—

(*a*) Mechanically operated.
(*b*) Electrically operated.

For small installations the former is a distinct aid to the service as, when installed at each landing door, it forms a means of notifying a waiting passenger that his call is being answered, and he therefore waits more patiently for the car than he would otherwise probably do. In low buildings they also enable a passenger to determine whether it is worth while waiting for the car.

When applied to grouped lifts and fixed at the ground floor, they enable the "Starter" or foreman to observe the operation of each car and how they are spread in the shafts. Any undue delay or loitering on the part of the operator can be immediately noted (Fig. 89).

For large installations, separate car position indicators become rather scattered and difficult to maintain under close observation. Grouping of the indicators then becomes desirable, and an ornamental bronze panel termed an "Electric Position Indicator" is the solution. It contains as many vertical rows of miniature lamps as there are cars in the group or groups, one lamp in each vertical row representing a floor served by the car. As the cars pass the floors, the lamps are illuminated, and the position of each and every car may be seen at a glance. By the addition of a "Starter's Signal" and a telephone to each car the electric position indicator may be converted into a complete control station.

For an installation of grouped cars, placed under the control of a "Starter," dispatcher, or foreman, an electric bell may be fixed in each car, the pushes corresponding to the bells being located at a convenient point in the hall or on the "Electric Position Indicator."

11. Telephonic Communication with Cars.—For important groups of lifts a special telephone equipment is a desirable addition to the equipment. In this case, instruments would be

fixed on the "Electric Position Indicator," in each car, in the engine-room, and, if this is in the basement, in the overhead gear chamber also. In addition to giving the dispatcher the means of keeping constantly in touch with the operators or attendants, the telephone has advantages in case of emergency, accidents, or when repairs are being made.

12. **Automatic Starting Signals.**—For a group of two cars it is frequently found to be desirable to hold one car at the top of the shaft and one at the bottom until a call is received or a sufficient number of passengers has boarded the car at the ground floor. One car then starts on its journey, and it is convenient to arrange for a buzzer automatically to signal the other car to start in the opposite direction so that the cars change places and again wait at the top and bottom landings until another trip is necessary.

13. **Motor Starting Timing Device.**—For larger groups, in which the cars run to schedule at intervals of thirty seconds or so, irrespective of the number of passengers in the waiting car at the ground floor, the desirability of installing a motor starting device of the bell-ringing type should be carefully considered. This apparatus which is fixed in the main hall, is motor-driven, and automatically rings a bell at regular intervals, the interval being adjustable between the limits of ten and thirty seconds.

14. **Travel and Trip Recorders.**—To enable accurate records to be obtained and statistics prepared for the purpose of comparing the cost of operation and repairs, instruments that will record the total mileage travelled and the trips made by each car are a desirable accessory (Fig. 90). By this means all costs can be reduced to a car-mile basis, and any fluctuations noted immediately. Similarly they are useful in checking the life of the ropes, and thus to determine if they are up to standard.

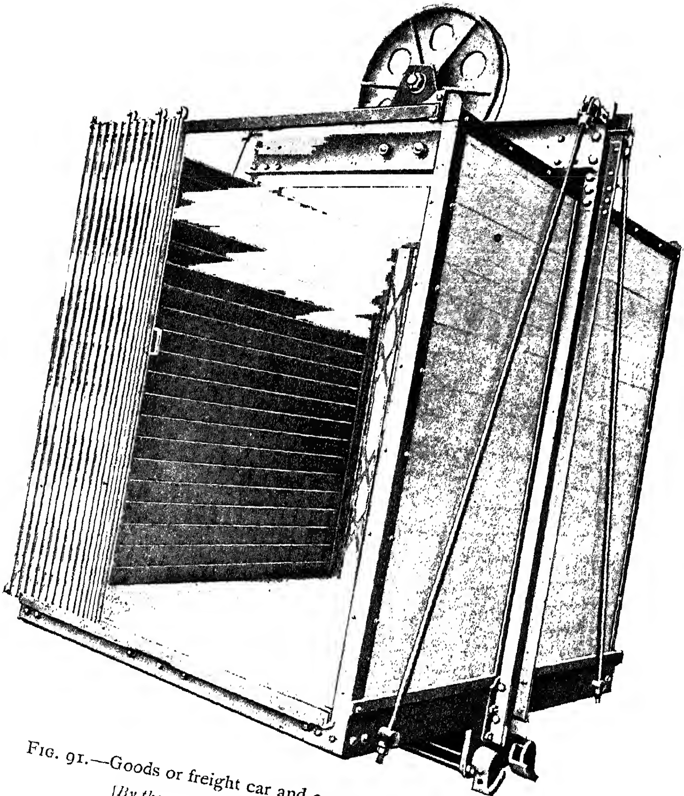


FIG. 91.—Goods or freight car and car sling roped two-to-one.
[By the courtesy of Messrs. Waygood-Otis, Ltd.]

[To face p. 113.

CHAPTER XVII.

GOODS OR FREIGHT LIFTS.

1. Estimating Service Requirements.—Goods or freight lifts cover an enormously wide field, as loads may vary from say 200 lbs. to several tons, and speeds vary from 30 to 250 ft. per minute, depending upon the purpose for which they are required.

There should not be any great difficulty in fixing the capacity of the lift as the requirements are usually fairly well known beforehand, and, from considerations of capital and operating costs, the speeds should be kept as low as possible.

2. Cars.—Cars may be built either of pitch pine, deal, or teak, tongued and grooved. Gates, as for passenger lifts, should be fitted to each opening of the car.

The height should be 6 ft. 6 ins. when designed to carry an attendant, and the load, unless otherwise determined, is figured at 100 lbs. per sq. ft. of floor area.

3. Car Sling and Safety Gear.—Since appearance is, as a rule, of secondary importance, car slings are somewhat modified in design, an angle iron framework being frequently provided to support the sides (Fig. 91).

When the car dimensions are such that it is possible for an attendant to ride in the car, safety gear should invariably be provided, but due to the low speeds employed it may be of the instantaneous, cam type.

4. Guide Rails and Fixings.—Guide rails are commonly supplied of well-seasoned deal or Oregon pine, but for heavy or fast-running lifts, and especially where silent operation is of importance, steel guides are recommended.

5. Summary.—The other details of the equipment follow standard passenger lift practice so closely that there appears to be little or no object in discussing these in detail.

CHAPTER XVIII.

SERVICE LIFTS OR DUMB WAITERS.

1. Definition and Field of Application.—A service lift or dumb waiter is practically a goods lift in miniature. So far as it is possible to trace there is no generally accepted definition of the term, although it is, as a rule, understood to refer to a lift that is too small for an attendant to ride in the car.[1] Under these circumstances the safety consideration is not so important, and the majority of safety devices are, as a rule, therefore not fitted.

The principal field in which service lifts are employed is the café, restaurant, or hotel, for conveying food from the kitchen or wine from the cellar to the still or service rooms adjoining the restaurant, grill room, coffee room, dining room, etc. Other applications are business premises for the conveyance of small stock between the stock room and the sales counter, and in factory buildings for conveying trays of small parts from one department to another located on different floors.

Since all the details of the equipment are, in practically all cases, modifications of standard passenger lift equipment, the various items will be discussed briefly in the same sequence.

2. Estimating Service Requirements.—For restaurant work, it will be found much more satisfactory in almost every case to provide at least one lift for each floor rather than to endeavour to economise capital cost by arranging for one lift to serve two or more floors. In any case, if only one lift is installed in the first instance, shafts should be built on the basis of one per floor or at least the floors should be trimmed for these.

Quick service is of vital importance in public restaurants, and in buildings in which the position of the kitchen in relation to the various service rooms is such that manual transport is impracticable, two lifts per floor are very desirable, or, failing this, one or more of the lifts should be so arranged that in the event

[1] "The term 'Dumb waiter' shall include such special form of elevator, the dimensions of which do not exceed 9 sq. ft. in horizontal section and 4 ft. in height, and which is used for the conveyance of small packages and merchandise" (Elevator Regulations, New York City, 1911).

of one lift being laid off for repairs, service can still be maintained to that floor by one of the lifts normally serving one of the other floors.

For buildings in which the total car travel does not exceed 30 ft. a car speed of 100 ft. per minute is practically standard, but should the distance exceed this figure, a speed of 150 or even 200 ft. per minute may be found necessary. In estimating travel time, the actual speed may be calculated at 80 per cent. of the rated speed, to allow for the periods of acceleration and retardation, i.e. for a car rated at 100 ft. per minute to travel a distance of 40 ft. would take approximately 30 seconds.

3. **Cars.**—Cars, which consist of a rectangular box, fitted with a shelf or shelves, not infrequently receive extremely rough treatment at the hands of the kitchen staff and should be of very substantial design and workmanship. The material employed in construction is usually $\frac{7}{8}$ or $1\frac{1}{8}$ in. deal or pine, convenient sizes being as follows:—

TABLE XVII.

Dimensions of Service Lift Cars.

Size.	Width.	Depth.	Height.
Small . . .	18 ins.	15 ins.	24 ins.
Large . . .	18 ,,	18 ,,	27 ,,

Experience indicates that for satisfactory service, the smallest possible cars should be employed that will handle the legitimate traffic, in order to prevent the use of the lift for the conveyance of unauthorised articles such as dust and coal bins, milk churns, laundry baskets, ice blocks, etc., that are only suitable for conveyance by a goods lift. In this connection it may be said that removable shelves, although possibly useful as a talking point for salesmen, are a source of constant trouble in practice, and, if supplied in the first instance, are frequently securely fixed by the maintenance staff for the reason indicated above.

In private houses, the load seldom exceeds 20 to 25 lbs., in restaurants 40 lbs., but in public institutions, such as hospitals, asylums, etc., it may rise to 90 lbs. Standard English ratings are 56 and 112 lbs., and also 2, 3, and 4 cwts. Standard American ratings are 50, 100, and also 200, 300, and 400 lbs. As a matter of fact it is extremely difficult to say definitely where

the line of demarcation between service and goods lifts should be drawn on the capacity basis, apart from the fact that the average weight of a passenger is figured at 150 lbs. See also footnote to par. 1.

Preferably, cars should be built shallow and wide rather than narrow and deep, and every endeavour should be made to avoid the provision of two entrances. It is unusual to provide car gates or shutters, and unless there is a solid back to the car, the load is not infrequently pushed partly through the opposite opening in the hurry experienced at rush times. Should this happen and the load come into contact with some projection in the shaft, derailment of the car is the probable result.

It may almost be laid down as a maxim that cars with two openings will inevitably prove a constant source of trouble and complaint notwithstanding the provision of deep lips to the shelves.

Electric hot plates may be fitted to cars intended for the conveyance of hot dishes, liquids, etc., in hotels, in order to prevent them becoming chilled during transit.

4. **Car Slings.**—Car slings, if employed, usually consist of two uprights, to which the four guide shoes are attached, and an upper and lower cross-beam, the ends of which are mortised to the uprights.

Safety gear is seldom if ever fitted as the car is employed solely for goods traffic. The loads are relatively small, so that even should the car fall, due to rope failure, the damage should not exceed broken crockery and spoiled food.

5. **Guide-rail Fixings.**—When silent operation is important, 1-in. round steel guide rails should be employed both for the car and for the balance weight, although where first cost is important scarfed and grooved deal guide rails are frequently installed for the balance weight and also for the car.

To reduce cost of installation and materials, several makers have designed special types of steel guide rails that are common both to the car and to the counterweight.

6. **Counterweights.**—Counterweights should be of the pocket or adjustable type, described in Chapter VI., but of a more simple character in view of the smaller loads to be balanced.

7. **Suspension Ropes and Rope Fastenings.**—Two ropes only are employed as a rule, the diameter depending on the load for which the car is rated.

8. **Drive and Methods of Roping.**—Makers are almost equally divided between the drum and the half-wrap traction

form of drive. In practically all cases the control is full automatic push button, and for installations in which vee-sheave drive is adopted the tappet switch system of floor selection, located in the shaft, is provided.

This is undoubtedly a cheaper method than the drum drive and positively driven floor selector switch, but the latter will probably be found more reliable in practice, since all contacts, except the door safety switches, are in full view. Nevertheless, thousands of vee-sheave service lifts operating in conjunction with shaft tappet switches are in daily use and give every satisfaction.

The advantages of the two methods of drive have already been discussed in Chapter VIII.

9. Winding Engines.—Single worm-geared engines are universally employed, the motor, brake, and gear being mounted on a combined cast-iron bed-plate. This should be designed with oil-retaining grooves in order to prevent oil leakage into the shaft. For lifts in which drum drive is employed a chain sprocket is frequently mounted on an extension of the drum shaft for the purpose of driving the floor selector switch.

Regarding the position of the winding engine this is preferably at the top of the shaft, but almost equally good results can be obtained from basement engine-room installations, although, of course, the first cost is greater owing to the extra cable and overhead leading sheaves involved.

10. Electric Motors.—With these small motors, starting torque is rather more important than horse-power output at full speed, and series wound motors are therefore frequently employed where the supply is on the direct-current system, due to the fact that, in the smaller frame sizes, pole space is restricted.

Utilising the expression given in Chapter X. for horse-power, the figures in the following table were obtained :—

TABLE XVIII.

H.P. of Motors for Electric Service Lifts.

Car Capacity (lbs.).	Net Load at 40 per cent. Overbalance (lbs.).	Car Speed (ft./min.).	B.H P. at 35 per cent. Efficiency.
56	33·6	100	0·29
112	67·2	100	0·58
56	33·6	150	0·44
112	67·2	150	0·88
56	33·6	200	0·58
112	67·2	200	1·16

Actually, a motor rated for 0·5 b.h.p. would be used for the 56-lb. lift at 100 ft. per minute and a 1 b.h.p. motor for the 112-lb. lift at the same speed.

11. Brakes.—Brakes are similar in character to those described in Chapter XI., but are of suitable design for the smaller duty.

12. Control Gear.—Control is invariably of the full automatic push-button type, but the actual details vary with each installation, depending on local requirements.

For a car serving two floors only, one of the under-mentioned arrangements will probably meet the case :—

(*a*) Dispatch button only at each floor.
(*b*) Call buttons only at each floor.
(*c*) Call and dispatch buttons at each floor.
(*d*) Dispatch button only at kitchen floor. Action of closing the door in the service room dispatches the car to the kitchen.

When the car serves more than two floors one of the under-mentioned arrangements may be suitable :—

(*a*) Full set of dispatch buttons in the kitchen (one for each floor) in addition to "Stop" and "Call." Also one dispatch button at each of the other floors.

(*b*) For intermediate floor service, a complete set of buttons at each floor.

(*c*) Full set of dispatch buttons, also "Call" and "Stop" at kitchen. Closing of the door at the other floors automatically returns the car to the kitchen.

For the 0·5 b.h.p. motors, starting resistance in series with the armature may be dispensed with if the motor is provided either with a series field winding or one series and one shunt coil.

The floor stopping device may be either of the selector type mounted in the engine-room and positively driven from the drum shaft, or on the tappet switch system which is employed when vee-sheave drive is adopted (Fig. 92).

13. Shafts and Engine-rooms.—Shafts may be of brick, concrete, slabs, plaster, or metal lathing, or even of match boarding, but the latter is not recommended, and is prohibited in certain districts under building regulations or bye-laws.

As with passenger lifts, overtravel spaces should be provided for the car both at the upper and the lower limits of travel. Three feet is desirable, but 2 ft. 6 ins. will suffice.

Clearances between the car and the walls of the shaft vary considerably with the type and arrangement of guides and the

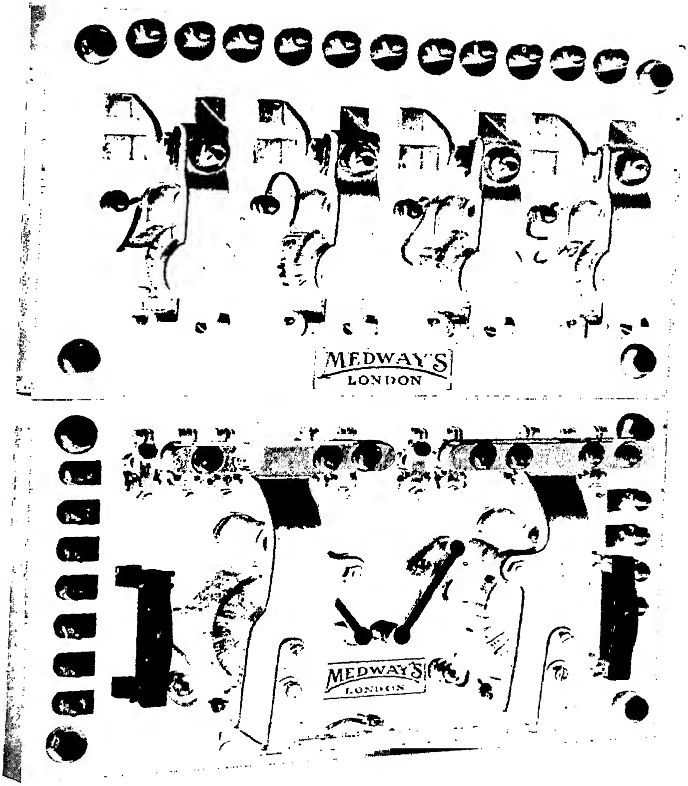


FIG. 92.—Service lift or dumb waiter d.c. control panel containing four floor relays (top) and main reversing switches (bottom).

[By the courtesy of Messrs. Medways, Ltd.]

[To face p. 118.

design of the counterbalance. If the wall climbing type of guide is used, 3 ins. at each side, 6 ins. at the back, and 1 in. in front should be ample.

Engine-rooms should be 6 ft. 6 ins. high at least if a battery of lifts is to be installed and the engines grouped, but where only one lift will meet requirements, it may be stowed away in a cupboard at the top of the shaft. In this case, all accessible sides of the cupboard should be arranged as removable panels, to facilitate examination, cleaning, and repairs. If the cupboard is of wood it should be well ventilated and lined with asbestos sheet or other fire-resisting material. It is undesirable to locate alternating-current motors in cupboards adjacent to occupied rooms if silent operation is an important factor.

Openings in the hatchway should be made 3 ft. from the floor to the sill and 3 ft. high, the width depending on the dimensions of the car. Allowing for 3 ft. overtravel space, the height from the floor to the underside of the leading sheaves on engine-room floor should therefore be 9 ft.

14. **Doors.**—Doors are invariably of the vertical sliding type, made either in one or two parts. In the latter type the two parts are geared together so that they move at equal speed in opposite directions. Wired glass panels should always be provided so that the arrival and departure of the lift may be observed. Lamps in the cars or fixed over the doors and operated by automatic contacts may also be provided visually to signal the arrival of the car.

Shaft doors on busy lifts are opened and closed many times per hour, and lubrication of the sliding surfaces is frequently neglected so that wear is considerable if the doors are not of the most substantial design and construction. Wear between the door and the frame means lost motion on the electrical interlock, and in the majority of cases lost motion on interlock involves stoppage of the lift that usually occurs at the busiest time.

To stand up to these heavy duties and to take care of shrinkage in the wood, due to the heat of the kitchens, the author eventually found it necessary to frame the doors in steel and to provide a steel frame for them to slide in. Until this method was adopted, endless trouble was experienced with the safety locks and switches due to lost motion between the doors and the frame.

15. **Safety and Protective Devices.**—The only safety devices that are commonly fitted to service lifts are door safety locks and switches and shaft limit switches. The former are

designed to prevent the normal operation of the car unless every door in the shaft is locked in the closed position, and the latter are provided to stop the car should the floor switches, at either limit of the travel, fail to operate. Locks and switches should be of the combined type, and of a type such that it is impossible for the switch to close if the door fails to lock. In installations in which the car serves more than two floors, owing to the restricted dimensions of the shaft and the difficulty of access to faulty contacts located in the shaft, it is advisable to provide a method, whereby the authorized person can release the lock and open any door, irrespective of the position of the car.

16. Signalling Devices.—Speaking tubes or electric bells are the signalling devices most frequently employed for the operation of service lifts, although the new loud-speaking telephones would undoubtedly be found beneficial in many installations.

Car position indicators, of the mechanical dial type, are occasionally installed when the car is arranged to serve several floors, and a full set of push buttons is provided for each floor.

CHAPTER XIX.

INSPECTION AND TESTS.

1. **General.**—On the completion of an installation of electric lifts, tests are usually made to see that all parts of the equipment are in good working order, that the speed and load requirements have been met, and that the safety equipment can be relied upon satisfactorily to operate as and when required. The principal points that should receive attention are outlined below.

2. **Inspection.**—A careful inspection of all details of the plant should be made to see that the contract has been executed in a thoroughly satisfactory and workmanlike manner. Points to note are conduit and cable supplying current to the motor; main switch and fuses; control panel; leads from control panel to motor; engine bed; foundation bolts, bed-plate level in both directions, all bolts and nuts tight, gear box and bearings supplied with oil; rope fastenings to drum and rope fits grooves; floor levelling device; ropes; overhead sheaves and lubrication arrangements; guide rails, fixing and joints; car, car switch, and gate; signalling system; landing doors, electrical interlocks and wiring for same; balance weights and rope connections, etc.

3. **Speed and Load.**—Weights equivalent to the rated capacity should be placed in the car and convenient points measured off in the shaft, allowing sufficient space for acceleration and retardation. Full speed can then be checked on both the upward and downward journeys, and should not vary by more than 15 per cent.

Similar tests should be made with a load of 150 lbs. (attendant) only in the car. The figures obtained for speeds with minimum and maximum loads in the car can then be compared.

4. **Acceleration and Retardation.**—Acceleration and retardation should be checked with minimum and maximum load in the car to see that it is smooth and even under both conditions and in both directions of travel.

5. **Safety Gear.**—The test required to prove the car safety gear and the guide grips will vary with the type installed.

For lifts in which a separate safety rope is provided the actual conditions can usually be reproduced by placing full load on the car and operating the safety rope, when the guide grips will act and take the weight of the car on the guide rails.

If direct-current motors and centrifugal governors are used, an adjustable resistance may be connected in the shunt field and the speed of the motor thereby increased until 40 to 50 per cent. in excess of rated speed is attained, at which point the governor should seize the safety rope and operate the guide grips. The motor speed should be read by means of a tachometer so that the actual speed at the point of tripping may be accurately ascertained. This test is only practicable when the car travel exceeds 30 ft. and the normal speed exceeds 100 ft. per minute.

For lifts fitted with safety gear that can only operate in the failure or unequal stretching of the ropes, the weight may be temporarily taken by a hemp rope or a special trip hook so that the car can be dropped by the cutting of the rope or by tripping the hook.

6. **Adjustment of Guide Shoes.**—Ride in the car and observe if there is any objectionable side or end play, due to failure of the erector correctly to adjust the guide shoes.

7. **Limit Switches.**—With full load in the car, run the car at full speed into the limit switches both at the top and at the bottom of the shaft. Then cut out the limit switches and repeat the test with the ultimate limit or overtravel switches only.

8. **Starting and Running Current.**—With full load in the car observe the starting kick and the normal running current and check this with the rating plate on the motor. Using a dead beat ammeter, allow 5 per cent. kick on first rush. The accelerating current should, in normal cases, not exceed 35 per cent. on a direct-current motor and 200 per cent. on an alternating-current motor.

Gradually reduce the load in the car until the current on the up trip is equal to the current on the down trip. At this point the load in the car should normally equal 40 per cent. of the rated car capacity.

9. **Safety Interlocks.**—Check the operation of all safety interlocks fitted to landing doors.

10. **Heating.**—Run the car for a mile at capacity load and observe acceleration, retardation, and also any excessive noise or vibration. Immediately afterwards, switch off the current

and observe the temperature of all bearings, gears, motor parts, switch contacts, brakes, resistances.

11. Insulation Tests.—Take insulation tests of motor, central gear, and wiring, and localise cause of low readings (if any).

12. Signalling Devices.—Carefully check the operation of the signalling equipment.

13. Car Attendant.—See that the regular attendant or resident engineer thoroughly understands the adjustment of brakes, oiling, cleaning of commutator, switches, etc., and the proper steps to take should the safety gear be brought into operation.

14. Spare Parts, Working Instructions.—Check over the list of spare parts to be supplied, and see that a card of "Working Instructions" is securely fixed in the engine-room or other convenient place, bearing the name and telephone number of the nearest lift service depot.

See also *Mechanical Equipment of Federal Buildings*, Nelson S. Thompson.

CHAPTER XX.

POWER CONSUMPTION.

1. Basis of Comparison.—It is a very difficult matter indeed to obtain any common basis, whereby the performance of different lifts may be satisfactorily compared, due to the large number of variable factors, i.e. car operators or drivers, loads, speeds, number of stops per car mile, weight of moving parts, unbalanced load, type of gear, etc.

However, it is possible to compile records for the purpose of comparing the performance of—

(*a*) The same lifts from time to time in order to detect any lowering of efficiency of operation, due to lack of lubrication, incorrect brake adjustment, etc.

(*b*) Similar lifts in the same building as a check on the skill of car attendants.

(*c*) Different types of lift operating under similar conditions in different buildings.

TABLE XIX.

POWER CONSUMPTION (H. P. Reed).

(By the courtesy of the American Institution of Electrical Engineers.)

Capacity. Lbs.	Speed. Ft./min.	Over-balance. Lbs.	Stops per Car Mile.	Miles per Day.	K.W.H. per Car Mile.		Type of Engine.
					Balanced.	Full Load.	
2000	350	—	—	11·25	—	3·98	Drum type geared.
2500	500	800	50	—	2·22	3·39	Gearless: full wrap 1 : 1.
,,	,,	,,	150	—	4·28	5·93	
,,	,,	1060	52	—	—	3·22	Gearless 1 : 1.
,,	,,	,,	104	—	—	3·86	,,
3000	,,	1175	100	—	3·90	6·00	Gearless, full wrap 2 : 1.
,,	,,	,,	200	—	5·80	8·71	
2500	600	—	16	—	—	2·40	Geared half-wrap traction.
,,	,,	—	96	—	—	5·20	
2250	500	580	50	—	2·10	3·00	3 to 1 speed.
,,	,,	,,	150	—	3·57	4·90	Variation by shunt control.
,,	,,	,,	400	—	6·95	8·50	

2. Car-mile System.—Hitherto, in England, the tabulated results have appeared in various forms, the most popular being round trips per Board of Trade unit or kilowatt-hour.

In America, when Mr. Frank J. Sprague became interested in electric elevators he introduced the system of car-mile comparison, borrowed from electric railway practice, and in that country it has become customary to compare lift systems by the consumption of kilowatt-hours per car mile run by the elevators. (See Chapter XVI. for details of travel recorders.)

Although this method is far from ideal, it affords a convenient comparison of plant designed for similar duties in buildings of similar service character, and it is useful in estimating the energy consumption of any given installation when the car mileage is known or can be assumed.

Clearly, the power consumption is largely determined by the number of starts and stops and not by the load carried in the car.

3. Power Consumption per Car Mile and Car Travel per Day.—Mr. Nelson S. Thompson (*Mechanical Equipment of Federal Buildings*) gives the following figures:—

> "Kilowatt-hour consumption per car mile for drum machines in Federal buildings averages five per car mile. Car travel per day in office buildings ranges from 10 to 20 miles, but it is stated that in the Singer Building in New York, the tower elevators average 30 miles per day each."

Mr. Harrison P. Reed (*Journal A.I.E.E.*) gives the following:—

(*a*) "Fifteen-story building; car capacity, 2750 pounds; car speed, 500 ft. per min.; car stops per mile, 100; energy consumption, 3·32 to 4·73 k.w.h. per car mile.

(*b*) "Twenty-two floors, 600 ft. per min.; elevator, with express service to the tenth floor, and local service from the tenth to the twenty-second floor, averaged 22 car miles per day, and 3·5 k.w.h. per car mile. Locals operating in the same building at 400 ft. per min. averaged 4 k.w.h. per car mile each.

(*c*) "Eighteen-story building, 400 ft. per min.; car travelled 21·8 miles per day for 3·28 k.w.h. per car mile.

(*d*) "Thirteen-floor building, 400 ft. per min.; car travelled 19 miles per day, and consumed 3·88 k.w.h. per car mile."

The car mile method of recording travel is clearly a useful basis for checking repairs, oil consumption, life of ropes, etc.

CHAPTER XXI.

OPERATION AND MAINTENANCE.

1. Division of Responsibility.—Assuming that complete co-operation between the architect and the engineer has resulted in the provision of an installation of electric lifts that is agreed, by all concerned, to be absolutely satisfactory in every respect for the purpose for which it was designed, the responsibility for maintaining the 100 per cent. service standard rests primarily with the owner or agent, and, secondly, with the operating staff. The car attendant is responsible for the control of the car, and the resident or visiting engineer is responsible for the cleaning and maintenance of every item that is included in the equipment, e.g. motor, controller, gear, sheaves, ropes, guide rails and guide shoes, balance weights, brakes, and the various safety and protective devices.

Too often owners of buildings appear to think that lift machinery needs no skilled attention, and it is a testimonial to the lift makers that the accidents recorded (both fatal and non-fatal), considered as a percentage of the total passengers carried, is so small.

2. Car Attendants.—The duties of an attendant, who is responsible for the control of a modern high-speed passenger car, considered superficially, appear to be of an extremely simple character—in fact, such as any intelligent schoolboy could carry out with entire satisfaction, both to owners and passengers.

Actually, the position is one of very considerable responsibility that demands constant vigilance, tact and courtesy, a cool head and presence of mind in the event of emergency, such as fire, excessive speed, etc.

He should be careful and cautious, smart in appearance, have a good manner of address, and be discreet, both in his own and his employer's interests, should an accident occur. Before being detailed off to take sole charge of a car, the attendant should be thoroughly instructed in his duties by a competent person, and be impressed with the responsibilities of his position.

2. Car-mile System.—Hitherto, in England, the tabulated results have appeared in various forms, the most popular being round trips per Board of Trade unit or kilowatt-hour.

In America, when Mr. Frank J. Sprague became interested in electric elevators he introduced the system of car-mile comparison, borrowed from electric railway practice, and in that country it has become customary to compare lift systems by the consumption of kilowatt-hours per car mile run by the elevators. (See Chapter XVI. for details of travel recorders.)

Although this method is far from ideal, it affords a convenient comparison of plant designed for similar duties in buildings of similar service character, and it is useful in estimating the energy consumption of any given installation when the car mileage is known or can be assumed.

Clearly, the power consumption is largely determined by the number of starts and stops and not by the load carried in the car.

3. Power Consumption per Car Mile and Car Travel per Day.—Mr. Nelson S. Thompson (*Mechanical Equipment of Federal Buildings*) gives the following figures:—

> "Kilowatt-hour consumption per car mile for drum machines in Federal buildings averages five per car mile. Car travel per day in office buildings ranges from 10 to 20 miles, but it is stated that in the Singer Building in New York, the tower elevators average 30 miles per day each."

Mr. Harrison P. Reed (*Journal A.I.E.E.*) gives the following:—

(*a*) "Fifteen-story building; car capacity, 2750 pounds; car speed, 500 ft. per min.; car stops per mile, 100; energy consumption, 3·32 to 4·73 k.w.h. per car mile.

(*b*) "Twenty-two floors, 600 ft. per min.; elevator, with express service to the tenth floor, and local service from the tenth to the twenty-second floor, averaged 22 car miles per day, and 3·5 k.w.h. per car mile. Locals operating in the same building at 400 ft. per min. averaged 4 k.w.h. per car mile each.

(*c*) "Eighteen-story building, 400 ft. per min.; car travelled 21·8 miles per day for 3·28 k.w.h. per car mile.

(*d*) "Thirteen-floor building, 400 ft. per min.; car travelled 19 miles per day, and consumed 3·88 k.w.h. per car mile."

The car mile method of recording travel is clearly a useful basis for checking repairs, oil consumption, life of ropes, etc.

on duty. (This will prevent any unauthorised person operating the car.)

(*j*) "When the car is in motion, never take your hand off the handle of the car switch (even if this be possible without stopping the car), so that you can stop the car immediately should the necessity arise.

(*k*) "Bring the car to rest before applying the power to travel in the reverse direction.

(*l*) "Do not allow your attention to be distracted when the car is in motion and wake up to find that you have run down heavily on to the buffers and opened the ultimate limit switches from which you cannot back out without assistance.

(*m*) "If instructed to do so, test the landing limit switches daily.

(*n*) "Report at once to the engineer-in-charge, anything unusual in the operation of the lift that you may notice, such as the faulty operation of car or landing door interlocks, excessive side or end play of the car, excessive movement of the car in either direction after the car switch handle is moved to the 'Off' position, sluggish or ultra-rapid acceleration, excessive noise or grinding, bumping guide rails, brake gripping too soon or too late, etc.

(*o*) "Make yourself thoroughly familiar with the safety gear and the other devices fitted to the car, such as the emergency call bell, the emergency release switch, the emergency switch, the emergency exit, etc.

(*p*) "Should your controller get out of order when the car is in motion and you find yourself unable to stop the car, place the controller handle in the 'Off' position and wait for the landing limit or the ultimate limit switch or the guide grip safety to function. Do not let the passengers know that anything unusual has occurred or they may endeavour to open the car gate and to jump out.

(*q*) "Should the guide grip safety operate, place the car switch handle in the 'Off' position and inform the passengers calmly and deliberately that there is no danger and that the power has been shut off. Indicate to them quite clearly that you understand your business and you will find that confidence in yourself will go a long way to reassure your passengers. Communicate calmly with

the lift starter, dispatcher, or hall porter by means of the telephone or emergency bell and ask for assistance. Do not attempt to use the emergency exit unless instructed to do so by the authorised person. He may get your car moving just as some one is passing out.

(*r*) "In the event of fire, keep calm, and if necessary use the emergency release switch so that you can run your car, even although some of the landing doors be open or damaged. Many lives may depend on your efforts in the few minutes available.

(*s*) "In the event of an accident, be guarded in your remarks. 'Chatter not in haste lest ye repent at leisure.' One or two incautious remarks made on the spur of the moment may require a lot of explanation later. Obtain the names and addresses of passengers present who witnessed the accident, as they may be useful later."

4. **Maintenance.**—The duty of maintaining a modern high-speed electric passenger lift installation in a safe and efficient condition is one involving very considerable responsibility and calls for intimate knowledge of the construction of lift machinery and a practical electrical and mechanical engineering training.

Eternal vigilance is the price that the engineer-in-charge must pay for a clean record free from accidents, and prompt action must be taken when defects are found to exist. Procrastination may result in attendance at a coroner's inquest.

For convenience, the principal points that require to be noted at the daily or weekly inspection are tabulated below in the order that has been adopted throughout the book :—

Detail.	Action.
Collapsible car gates .	Oil pins and roller tracks occasionally. Keep free from rust. Note any undue wear or stiffness.
Car	Replace faulty lamps.
Guide-rail shoes . .	Check fixings, adjust as required and lubricate.
Safety gear . .	Keep free of rust, lubricate, and test periodically to see that it is working freely and acts promptly and within a reasonable distance. Examine safety ropes and see that governor is in good order.

Detail.	Action.
Guide rails	See that all fish-plates and fixings are firm. Clean rails occasionally with paraffin or kerosene, and lubricate with seven-eighths cylinder oil and one-eighth plumbago. If automatic lubricators are fitted, replenish the reservoirs and attend to the wicks.
Balance weights	Check the fixing bolts, rope connections, and guide-rail shoes.
Suspension ropes	Examine carefully, clean with paraffin or kerosene as required, and lubricate with a slight trace of vaseline (see Chapter VII.). Check all rope fastenings and spring-loaded draw-bars or rope equalisers.
Winding engines	Check all foundation, bearing cap, and coupling bolts, shaft keys, etc. Examine worm wheel or worm for wear, test sample of oil from gear case for dirt, grit, or cuttings, and check oil level. Check condition of stuffing box and clear away surplus oil. Check end play on worm shaft and adjust the thrust coupling as required to reduce end play. Examine all oil wells and replenish as required.
Electric motors	Remove any surplus oil, clean commutator or slip rings, examine and bed brushes, blow out armature, check all connections, oil wells, and oil rings. With a.c. slip ring motors, be particularly careful to check all motor connections and contacts.
Brakes	See that the brake drum is free from oil, shaft keys are tight, shoe surfaces are in good order and properly adjusted so that they do not grip too soon or too late. Check connections to the solenoid and remove any surplus oil.
Control gear	Examine all contacts and smooth off any burnt copper, polish metal

Detail.	Action.
	contacts with smooth emery paper, and smear with a trace of vaseline. Examine all connections, resistances, etc., and test the action of all switches, relays, and rheostats. Note specially the action of any oil or air dash-pots. Remove the cover of the car switch or push-button box, and clean contacts if necessary. Examine carefully the condition of the contacts on floor selection switches.
Landing doors . .	Examine carefully the condition of all interlocks, tracks, and rollers, and clean, oil, and adjust as required.
Car safety switch, terminal limit switches, overtravel or limit switches, slack cable switches, compensating cable switch, phase-failure and phase-reversal relays.	Examine carefully, polish contacts and smear with a trace of vaseline. Check all cable connections and note any signs of overheating.
Buffers . . .	Check fixing bolts and note condition.
Signalling systems .	Check the operation, replace faulty lamps and renew batteries as required.

After repairs have been effected, closely examine every part and test the operation of the lift by noting the action of the controller, winding engine, sheaves, ropes, etc., in the engine-room and also by riding in the car.

Should the friction safety gear operate use extreme care in releasing it. Note particularly any slack in the ropes before acting, and, if this exists, have the strain placed on them before releasing the gear.

Similarly, if the car attendant has run the car into the ultimate limit switches, examine carefully the condition of affairs before taking action and note in which direction the car has to be moved, in order to back out.

Never allow a car to be used unless the friction safety gear is known to be in perfect order. It should be regarded as the safety valve of the lift.

CHAPTER XXII.

ESCALATORS.

1. Historical.—The "Escalator" or moving stairway was first exhibited by the Otis Elevator Company of New York at the Paris Exhibition in the year 1900, and was an instantaneous and popular success. This was probably due to the fact that without any loss of time in waiting for the arrival of a lift car, one may step upon the escalator and be carried upward or downward at a moderate speed comfortably, safely, and without physical effort.

2. Capacity.—One of the most extraordinary features of the escalator is its remarkable capacity for carrying large numbers of people. A few examples worked on the data given in Chapter II. will clearly show that the capacity of any lift car has very marked limitations, whereas an escalator can be designed without difficulty to handle 11,000 passengers per hour, and, furthermore, there is no time lost in starting, stopping, loading, and unloading.

3. Types of Escalator.—There are two principal types of escalator, viz. :—

(*a*) The step type (Fig. 93).
(*b*) The cleat type (Fig. 94).

Both types of escalator can be made to operate in either direction by employing a reversing switch and are then termed reversible escalators.

When traffic must be handled in both directions simultaneously, two machines are used, one moving upwards and one moving downwards. Such an arrangement is then known as a duplex escalator.

4. Step Type.—In this type, the treads, when on the landing are flush, thus forming a moving platform on to which the passenger steps from the stationary floor plate. As the steps approach the incline, the wheels rise on the curved tracks, producing a step formation gradually at first and more rapidly

thereafter until the inclined portion is reached, at which point the full riser is developed. At the top, the steps flatten out again into a moving platform, from which the passenger steps to the stationary floor.

On either side, a hand-rail of flexible material moves upward at the same speed as the steps, thus providing the passengers with a steady support as they ascend.

Should a passenger absent-mindedly or through nervousness, fail to step off on arriving at the top, the balustrade that turns inward, and under which the moving platform disappears, will gently push him off on to the stationary landing without any serious inconvenience.

The angle of inclination in this type is usually 30° and the width of the step either 2 ft. or 4 ft., 90 ft. per minute being a convenient speed for a public escalator or 130 to 140 ft. per minute for factory employees who habitually use it (Fig. 95).

5. **Cleat Type.**—Briefly stated, the cleat type is a moving stairway without the steps! The step treads are formed of hard maple bolted to a steel bushed chain that passes over sprocket wheels at the upper and lower ends of the machine. Attached to the treads, at intervals of 1 ft., are self-lubricating steel wheels that roll upon steel tracks.

The step treads are so nearly horizontal, the angle being $12\frac{1}{2}°$, that the foot of the passenger is in a very comfortable position while riding either up or down the escalator.

The surface of the moving plane is produced by a series of parallel cleats about 1 in. apart forming longitudinal ridges and grooves. The object of this arrangement is to land the passenger safely and comfortably at the floor line upon a comb-shape plate, the prongs of which project into the grooves, between the ridges of the treads. A moving hand-rail, similar in type to that described in the previous paragraph is provided with this type also.

The angle of inclination of the cleat type is usually 25° or twice the angle of inclination of the treads with the horizontal.

A typical cleat escalator 24 ins. wide, travelling at 90 ft. per min., will handle 3400 people per hour on a 25-ft. rise when driven by a 12 b.h.p. motor (Fig. 96).

Assuming the weight of the average passenger at 150 lbs., the theoretical horse-power is

$$\frac{3400 \times 150 \times 25}{60 \times 33000} = 6{\cdot}4$$

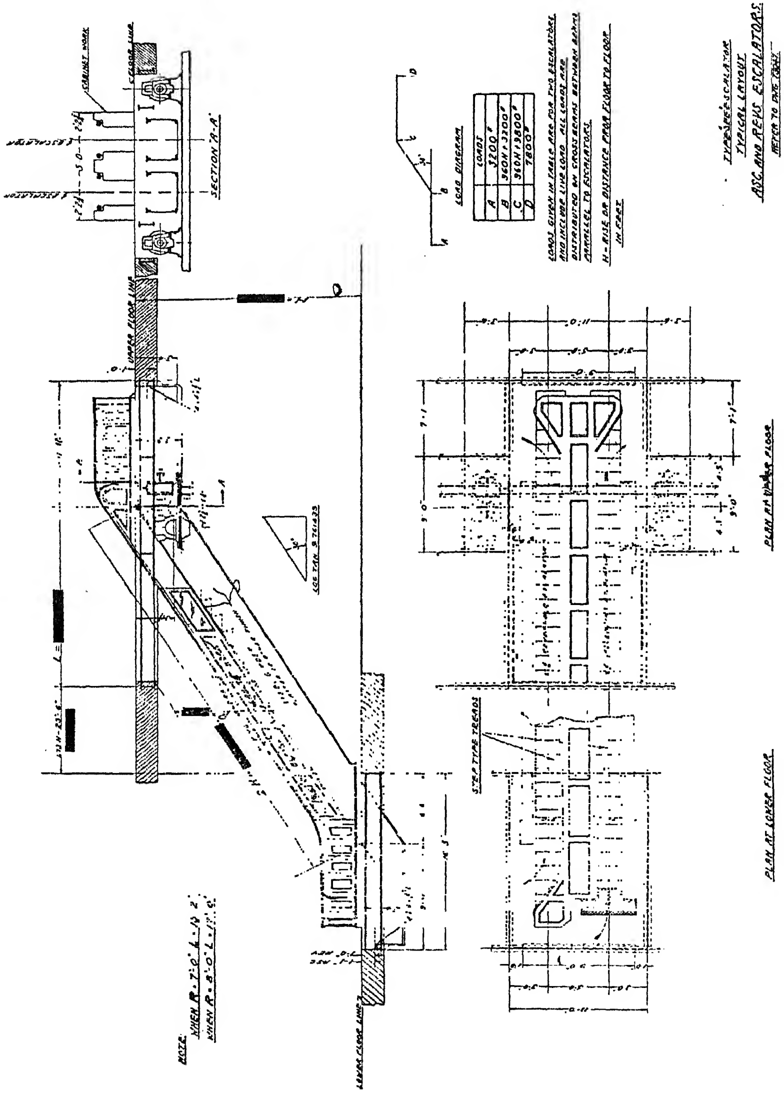


FIG. 95.—General arrangement of step type escalator.
[*By the courtesy of the Otis Elevator Co.*]

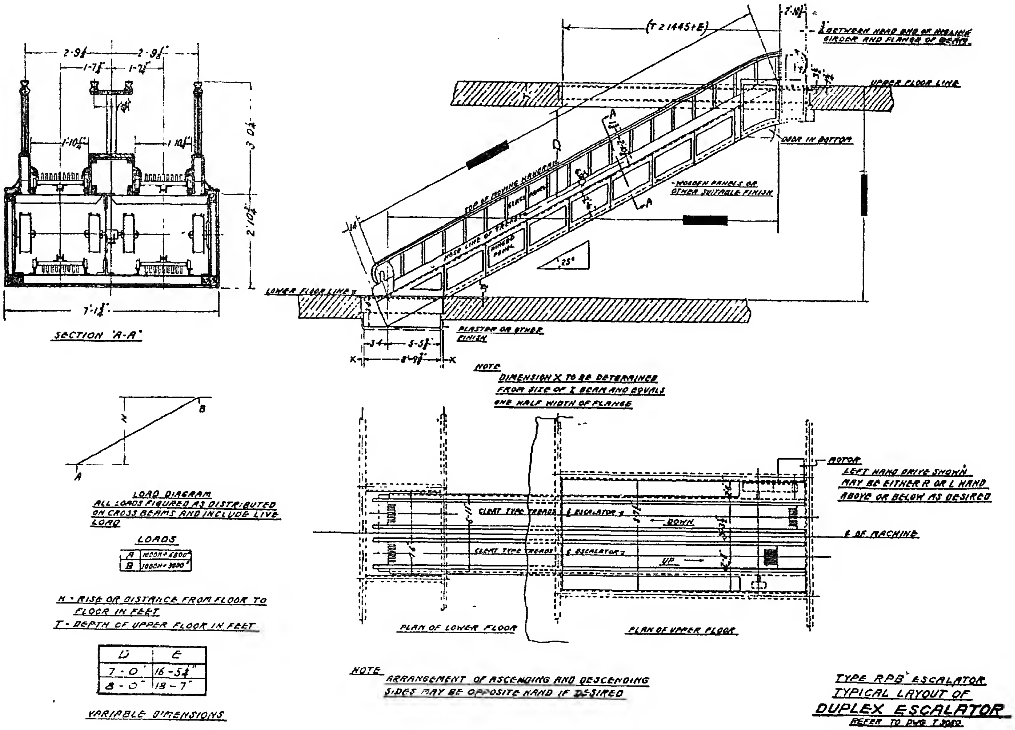


FIG. 96.—General arrangement of cleat-type escalator.

[*By the courtesy of the Otis Elevator Co.*]

and assuming the 12 b.h.p. motor to be fully loaded the efficiency would be

$$\frac{6 \cdot 4 \times 100}{12} = 53 \text{ per cent.}$$

This is rather a remarkable result considering the large number of wheels employed.

6. **Field of Employment.**—Escalators in England are almost exclusively restricted to the "Underground" railway, but in America they are extensively employed in mills, factories, hotels, departmental stores, and in legitimate and kinema theatres for conveying patrons to the balconies and galleries.

CHAPTER XXIII.

ACCIDENTS.

(For tables see Appendix.)

1. English Reports.—From the Annual Report of the Chief Inspector of (English) Factories and Workshops for the year 1920, it would appear that 36 fatal and 512 non-fatal accidents were directly attributable to lifts and hoists installed in factories and workshops, but it is doubtful if this list is by any means complete as, of course, large numbers of lifts are fixed in buildings that do not come within the scope of the Factory Acts. In fact, if the building is less than 30 ft. in height, and employs less than twenty persons, exclusive of domestics, no report of a lift or hoist accident therein appears to be necessary. Should a fatal lift accident occur in a building which falls within the limits indicated, presumably the Coroner for the district would be the only public official directly interested.

The statistics referred to are also vitiated from the point of view of lift engineers, as many accidents, due to primitive forms of workshop and factory hoists, are included in the Report that make the situation appear very much worse than it is.

In Safety Pamphlet No. 2, "Protection of Hoists," issued by the Home Office, London, there appears the following note:—

"The number of hoist accidents reported year after year to the Factory Department indicates that the danger is not sufficiently realised by either employers or operatives.

"Hoist accidents are mainly due to one of three causes: (1) Failure of lifting ropes or mechanism; (2) Crushes between the cage and door lintels or other projections in the hoist well; (3) Falls down the well owing to unfenced conditions or inadequate fencing of the doorways. Of these (2) and (3) cause the majority of accidents."

2. American Reports.—*The Elevator Interlock Report*, issued by the U.S.A. Bureau of Standards, previously referred to, contains the following reference to the subject:—

"The statistics show that the largest number of accidents is caused by falling down the shaft, the weighted average percentage

of the total fatalities to the public from this cause being 36·9, and to industrial employees 36. In the case of non-fatalities, these percentages are, public 21·3, industrial employees 14·7.

"It should be noted that the percentage of all fatalities from falls is about the same for both classifications, public and industrial.

"This is a strong indictment of the ordinary door latch, and the results of the survey bear out the conclusion reached by a study of accident statistics. A substantial latch should therefore be made a part of every interlock and the ordinary door latch discarded. A somewhat minor point which should not be neglected in the design of interlocks, since it bears directly on the hazard of falling down the shaft, is the possibility of opening the door from the landing side when the car is passing a landing. Devices which permit this should not be installed.

"The next most prolific cause is the crushing hazard; that is, the possibility of being crushed between car and sill of the landing floor or frame of the door. The average percentage of the total fatalities to the public from this cause is 36·9 and to industrial employees 18. In the case of non-fatalities the percentages are, public 18·7, industrial employees 38·5.

"These values, on comparison with those for causes originating within the shaft, show the necessity for interlocking the movement of the car with the opening and locking of the door, inasmuch as the unlocked door exposes the user to the hazard of falling into the shaft.

"Another cause of accidents resulting from lack of interlock devices is stepping into the shaft under the mistaken idea that the car is at the landing. A study of 978 elevator fatalities showed that 1·3 per cent. of the accidents were due to this cause, and of 1368 non-fatalities, the percentage was 0·9. This is a real hazard, and is comparable with many of the accident percentages due to causes originating within the shaft. It is recommended that provision be made against it."

In Philadelphia interlocks are compulsory on passenger lifts, and apparently the system of inspection is such that they are maintained in good order, for statistics show that not a single passenger, operator, or mechanic was killed in an electric lift during the entire year of 1918. The contrast with freight or goods lifts of all types, for which interlocks were not required, is very marked, during the same period 19 persons being killed and 22 injured, 2 being killed on electric lifts and 5 injured.

CHAPTER XXIV.

SPECIFICATIONS.

(The specification following is included for general guidance in drafting. It relates to the proposed installation of six electric passenger lifts in a modern office building. It is, of course, quite impossible to cover each and every variation that arises in connection with individual installations.)

1. Technical Details.

(*a*) No. of lifts to be installed .	6.
(*b*) Total travel	105 ft.
(*c*) Floors served	8.
(*d*) Type	Passenger.
(*e*) Car entrances	1.
(*f*) System and voltage of supply	D.C. 240/480 volts.
(*g*) Position of engines . . .	Top of shafts.
(*h*) Pit depth below lowest landing	4 ft.
(*i*) Car details :—	
Width (approx.) . . .	5 ft.
Depth (approx.) . . .	4 ft. 3 ins.
Area (approx.) . . .	21·2 sq. ft.
Passenger capacity . .	9 plus attendant.
Live load	1590 lbs.
(*j*) Shaft dimensions :—	
Width	6 ft. 1 in.
Depth	5 ft.
(*k*) Load speed	300 ft. per min.
(*l*) Control	Car switch.

2. Variations from Specification.—The specification following indicates generally the requirements of the proposed installation, but modifications suggested by makers will be carefully considered, if set out in detail and reasons are given for the proposals.

3. Materials and Workmanship.—All materials required are to be of the very best of their respective kinds, and the

installation is to be executed in the most thorough and workmanlike manner to the complete satisfaction of the architects.

4. **Noiseless Operation.**—Every possible and reasonable precaution is to be taken to eliminate noise from the motor, gear, brakes, controller magnet switches, car gate, and landing doors. Any special precautions required or necessary for this purpose that affects foundations, structural work, etc., to be set out in detail in the letter covering the tender.

5. **Drawings.**—Working drawings, in duplicate, to be submitted to the architect for his approval, one copy to be approved and signed by him and returned to the makers as authority to proceed.

6. **Scope of Contract.**—Contractor to furnish all labour and material necessary, erect lifts, make all necessary electrical connections and leave the installation in perfect working order.

With the tender, there is to be submitted a specification of builders' work that will be required by the contractor, and this work will be carried out free of charge to the contractor. Any additional work required by the contractor and not mentioned by him will be debited against the contract sum.

7. **Number of Lifts to be Installed, Type and Location.**—There will be six passenger lifts, located in the Lift Hall, three on each side, adjacent to the main entrance.

8. **Load and Speed.**—Each equipment to be designed to lift a live load of 1590 lbs., exclusive of car, car sling, etc., at a speed of 300 ft. per minute.

9. **Travel and Floors Served.**—The total travel of each car to be approximately 105 ft., serving eight floors.

10. **Shafts.**—Two shafts, each for three cars, of brick construction, all necessary protection from the weather, steel joists, and builders' work, will be provided under another contract.

The depth of the pit allowed below the lowest landing is 4 ft., and the distance allowed from the top landing to the under side of the engine-room floor is 16 ft. Should these spaces be insufficient, a statement to this effect, together with a drawing showing the space required, should be attached to the tender.

11. **Buffers.**—Two heavy spring buffers to be provided for the car and two for the counterweight, complete with the necessary fixing and foundation bolts. Counterweight buffers to be fixed in a manner such that the weight is taken when the car floor is 6 ins. higher than the top landing level.

12. **Guide Rails.**—For car preferably to be of "**T**" section steel not less than $4\frac{1}{2}$ ins. (back) × $3\frac{3}{8}$ ins. (web) weighing not

less than 14 lbs. per ft. run. For balance weight preferably to be of "T" section steel not less than $2\frac{3}{4}$ ins. × 2 ins. weighing not less than 7 lbs. per ft. Proposals for round steel rails will be carefully considered.

All guides to be securely fixed to the walls and to the cross joints by means of cast-iron palms in an approved manner.

Ends of guides to be tongued and grooved and fish-plates to be provided containing not less than eight $\frac{5}{8}$-in. bolt holes for the car rails and not less than eight $\frac{1}{2}$-in. bolt holes for the balance weight rails.

Lubricators both for balance weight and car guides to be of the wick type, provided with large capacity wells and hard fibre shoes to distribute the oil to both sides and the face of the rail.

13. **Car Sling and Guide-rail Shoes.**—Car sling to be formed of channel section steel, firmly riveted together and bound with corner plates as required.

Four guide-rail shoes of massive construction to be provided and securely fixed to the car sling. They are to be fitted with renewable wearing surfaces, be of a self-aligning type, and be fitted with spring take-up for side play.

14. **Friction Safety Guide-rail Grips and Overspeed Governors.**—To be of the drum-operated tweezer type securely fixed to the car sling below the car, having not less than $\frac{1}{8}$-in. clearance, and adjusted to operate within a distance of 8 ft. whenever the maximum speed limit of the car is exceeded by 40 per cent. in either direction.

Guide-rail grips to be operated by means of a separate standard lifting rope passing through a clamping device operated by a centrifugal governor located in the engine-room at the top of the shaft.

Provision to be made for releasing the guide grips without going under the car.

15. **Cars.**—Car, for which a p.c. sum should be included in the tender, to have one entrance to be of the all-metal and glass type of construction, generally on the lines of the sketch attached hereto and finished dull bronze. Dimensions to be approximately 5 ft × 4 ft. 3 ins.

Floor to be covered with best quality compressed cork flooring, not less than $\frac{1}{2}$-in. thick, securely fastened in place.

Entrance to car to be provided with a "Ricketts" or other approved type of threshold illuminator and with a top hung "Rax" patent mid-bar collapsible gate, suspended on ball-bearing rollers which run on an overhead track.

Include for electric light fitting, flush pattern switch and the necessary connecting cables. Also for capacity label, showing the maximum number of passengers to be carried.

16. **Suspension Ropes.**—Six of the best quality standard $\frac{6}{16}$ Swedish iron hoisting ropes, arranged in "Lang's Lay" to be provided, the combined breaking load being calculated on a total factor of safety of twenty times the gross load of the car, car sling, and safety gear plus the live car load of 1590 lbs. Ropes to be secured to the car and to the balance weight in an approved manner, and to be provided with equalisers or spring-loaded draw bars.

17. **Balance Weights.**—To be of the sectional type, so constructed that they cannot spread in the event of failure of the ropes, and be securely attached thereto in an approved manner.

Over balance to be 40 per cent. of the live load, subject to adjustment later when the average traffic has been ascertained. Safety gear is not required for the balance weights. Guide-rail shoes as for car sling.

18. **Winding Engines.**—To be of the single worm; full-wrap traction type, with gear box, motor, brake, and outer bearing mounted on a dowelled single, self-contained cast-iron bed-plate. Pads, planed or milled, and stiffening ribs to be provided to secure accurate alignment of all parts.

Bed-plate to be provided with raised edges or an oil-retaining groove to prevent oil dripping into the shaft.

Adjustable ball-bearing thrust blocks, oil-tight gauges and drain cocks to be provided.

Gear to be guaranteed to operate without appreciable noise.

Detailed specification of winding engines, which will be located at the top of the shaft, to be submitted with tender.

19. **Driving Sheaves.**—To be of best quality, grey cast iron, free from all imperfections, accurately turned and grooved for the size of cables to be used and to be not less than forty times the diameter of the lifting ropes.

Sheave and gear wheel to be mounted between bearings, both of which are to be mounted on the cast-iron bed-plate.

Bearings for sheave shaft to be of the self-oiling type.

20. **Motors.**—To be of the direct-current, shunt wound, protected, adjustable speed, crane rated type arranged for a minimum speed of approximately 425 r.p.m. with full shunt field and a running speed of 567-850 r.p.m. on shunt field control. To be specially designed for lift service, to develop high starting torque, for quick operation, sparkless commutation, to have ample overload capacity and to be of rugged and substantial construction.

The motor to be capable of developing a rated load of 18 b.h.p. continuous rating when connected to a 480 volt d.c. circuit and to be equipped with a short-circuited damping winding on the main poles to ensure smooth acceleration. Temperature rise at the end of a run of one hour at rated load and maximum speed not to exceed 90° F. above the surrounding air.

Flash test of 1000 volts a.c. to be applied for one minute between windings and frame immediately after completion of full load-temperature test, and the I.R. test, to be taken immediately afterwards, to be not less than one megohm.

Special attention to be paid to brushes and brush holders to avoid chattering in continuous use under rapid reversals of rotation.

Shaft to have an extension of 1¼ in. at the commutator end, cut square so that it can be turned by a wrench or key.

21. Magnetic Brakes.—Brake drum to be formed by the flanged coupling connecting the armature shaft to the drum shaft.

Brake shoes, which are to be provided with renewable friction linings, to be in two complete sections, so that either section will be effective in the event of failure of the other. The total retarding torque to be equal to the full load torque transmitted by the shaft.

Brake to be applied either by weights or spring and to be released electrically and arranged for adjustment through a wide range.

Provision to be arranged for releasing the brake pressure, should it be necessary at any time to turn the armature by means of the crank handle.

22. Control.—(*a*) *Type.*—Car switch, two speed, full magnetic, with dynamic brake.

(*b*) *Panel and Framework.*—To be of best quality slate, 1½ in. thick, free from metallic veins and treated to prevent the absorption of moisture. To be complete with angle iron framework for floor mounting in the engine-room.

(*c*) *Switch Gear.*—Full specification and illustrations or drawings of type offered to be attached to tender.

Switches of the butt or wipe type actuated by solenoids direct are preferred to long stroke solenoids, dash-pots, racks and pinions, pilot motors, cams, or sliding contacts.

The field circuit should be switched off at the completion of each trip and the reversal of the motor effected by reversing the armature connections.

Local push-button control to be provided, so that the operation may be tested from the engine-room.

Full details to be given of the method adopted of controlling the period of acceleration and of interlocking the direction switches.

(*d*) *Instruments.*—The following instruments are required for each lift control panel:—

(i) One 6-in. dial, dead beat, moving coil ammeter reading to 50 amperes.

(ii) One integrating watt-hour meter rated for 50 amperes at 480 volts.

(*e*) *Car Switch.*—To be of the "dead man" type, of neat and substantial design, finished to harmonise with the decorative features of the car.

Handle to be removable only in the "Off" position.

23. **Safety Devices.**—The under-mentioned safety devices to be provided and fixed:—

(*a*) Car gate switch.

(*b*) Landing limit switches in the control circuit (self-setting type).

(*c*) Ultimate limit switches in the main circuit (non-self-setting).

(*d*) Mechanical locks and switches for each landing door. Contact only to be made after the door is locked. An emergency switch to be provided in the car, fixed in a glazed case, to permit the operation of the car while the landing doors are open in an emergency.

(*e*) Switch operated by speed governor (main circuit).

Full details and illustrations to be submitted of the type of door and gate contacts and locks proposed. They must be of sound and rugged design to give satisfactory service under conditions of heavy traffic and rough usage.

24. **Signalling System.**—A complete signalling system to include the following to be quoted for as an extra:—

(*a*) Operator's car flashlight with landing push buttons.
(*b*) Passenger signal lanterns at all floors.
(*c*) Night service annunciator for two lifts.
(*d*) Starter's signal for each car.
(*e*) Electric position indicator for ground floor.
(*f*) Automatic starting signals.

25. **Landing Doors.**—To be provided under another contract.

26. Electrical Connections.—The power cable will be laid on to the engine-room and six d.p. ironclad switches and fuses each rated for 50 amperes will be provided under another contract. Similarly a fused lighting point will be provided in the centre of each shaft for the car light connections.

All other electric wiring required or necessary to be carried out by the lift contractor in 2500 megohm grade V.I.R. Taped and braided cable made by a member of the C.M.A. for the 480 volt circuit and 600 megohm do. for the 240 volt circuit.

All cables and wires, other than flexible conductors, to be drawn into heavy gauge, screwed, welded, and enamelled steel conduit securely fixed to walls and ceilings by saddles.

All outlets to be provided with external brass nipples to prevent abrasion.

The conduit to be electrically and mechanically continuous throughout, and screwed into all switches, door and gate locks, and other fittings.

Current density in and cable sizes to be as laid down in the I.E.E. Wiring Rules.

All conduit and metalwork to be earthed to the satisfaction of the architect.

Sweating thimbles to be provided for all cables of 7/036 S.W.G. and upwards.

27. Tools and Spares.—A complete set of spanners, mounted on a suitable angle iron frame, one crank handle for the winding engines, and a complete spare set of carbon brushes to be provided at the completion of the contract.

28. Painting.—All ironwork, except finished or working surfaces, to be painted two good coats of metallic paint, and all work exposed to view to have, in addition to the above, two good coats of white lead and pure linseed oil, tinted as directed.

29. Instructions.—The contractor to give the owner's representative all necessary instructions relating to the safe, economical, and proper care of the installation and operation of the cars.

A framed and glazed diagram of connections to be provided and securely fixed in the engine-room alongside the controllers.

30. General Clauses.—*Completion Date, Test and Acceptance, Current for Trials, Guarantee, Payment, Certificates of Insurance Co. and Electricity Supply Authority, Arbitration and other Clauses as usual.*

APPENDIX A.

CHECKING LIST.

(*From Sweet's Catalogue.*)

The function of this list is to serve as a guide and reminder in connection with the preparation of specifications and contracts and for making estimates.

1. **Type of Building.**
    (*a*) Dimensions.
    (*b*) Number of floors.
    (*c*) Use.

2. **Number of Lifts.**
    (*a*) Passenger.
    (*b*) Goods.
    (*c*) Pavement.
    (*d*) Service.
    (*e*) Escalator.

3. **Shaft Sizes and Openings.**
    (*a*) Openings on different sides.
    (*b*) Automatic or safety doors required.

4. **Travel.**
    (*a*) Number of floors for each lift.
    (*b*) Any cars to go to roof.

5. **Loads and Speeds.**
    (*a*) Maximum loading.
    (*b*) Average loading.
    (*c*) Speed required. (At what load and for each type of car.)

6. **Electricity Supply.**
    (*a*) Voltage.
    (*b*) System of supply.
        If alternating current—
            (1) No. of cycles.
            (2) No. of phases.

6a. **Type of Engine.**
    (*a*) Traction 1-1.
    (*b*) Traction 2-1.
    (*c*) Duplex tandem, helical worm gear.
    (*d*) Single tandem, helical worm gear.
    (*e*) Duplex tandem worm gear.
    (*f*) Single screw worm gear.
    (*g*) Spur gear.

7. Cars.

(*a*) *Design.*

(1) Allowed value exclusive of sling.
(2) Any special flooring for passenger cars.
(3) Any special flooring for goods cars.
(4) Any escape doors or traps.
(5) Special construction for pavement lift.
(6) Seats.
(7) Mirrors.
(8) Dimensions.

(*b*) *Lighting.*

How controlled.
Source and location of supply.

(*c*) Finish of Cars.
(*d*) Gates.
(*e*) Automatic doors.
(*f*) Safety hatches.
(*g*) Telephone from car to hall.
(*h*) Any temporary cars during construction.
(*i*) Allowed makes.

8. Signals.

(*a*) *Type.*

Flash.
Hotel type.
Auto target reset.
Magnet drop annunciators.
Allowed makes.

(*b*) *Pushes.*

Kind of pushes.
Cases.
Night service.
Signal cut-out in car.

(*c*) *Floor Dials.*

Design.
Finish.
Allowed makes.

(*d*) *Source of Supply.*

Any duplicate set.
Where is signal current derived from?

9. Lifting Ropes.

(*a*) Number.
(*b*) Diameter.
(*c*) Material.
(*d*) How equalised.
(*e*) Stretch in cables taken up by whom?
(*f*) Required safety factor.

10. Electric Cables.

(*a*) Number.
(*b*) Method of support.
(*c*) Quality.
(*d*) Protection.

11. **Counterweighting.**
   (*a*) Number.
   (*b*) What proportion of live load is to be counterbalanced?
   (*c*) How are filling weights to be secured?
   (*d*) Lubrication.
   (*e*) Shoes or gibs.
   (*f*) With two counterweights, how are ropes to bottom counterweight to be protected?
   (*g*) Sheathing.
   (*h*) Any chain counterbalance.
      How secured.
      Any covering.
      Any special construction to avoid noise.
      Any special construction to balance.
      Peculiar loading.

12. **Winding Engine.**
   (*a*) Traction or drum drive.
   (*b*) Motors.
      If d.c., shunt or compound.
      Maximum and minimum speeds.
      Lubrication.
      Time rating.
      Allowable temperature rise.
      Type, i.e. enclosed, ventilated, etc.
      Approved makes.
      Restrictions on current taken, power factor, etc.
   (*c*) Driving sheave or drum diameter and width.
   (*d*) How secured to motor.
   (*e*) Method of braking.
   (*f*) How mounted.
   (*g*) Rope grooves.
   (*h*) How ropes are led to car and counterweight.
   (*i*) Diameter and length of bearings.
   (*j*) Lubrication of worm gear machines.
   (*k*) Type of gear.
   (*l*) Speed reduction ratio.
   (*m*) Diameter of worms and gear.
   (*n*) Diameter of shafts.
   (*o*) Material of worm and gear shaft.
   (*p*) How is thrust taken and bearing adjusted?
   (*q*) Prevention of oil travel along shaft.
   (*r*) Method of alignment.

13. **Safety Devices.**
   (*a*) Excessive speed.
      Safety clutch operating on up motion.
      Safety clutch operating on down motion.
      Slowing down when speed increases above regular limit.
      Armature short circuiting.
   (*b*) Breaking of cables.
      Safety clutch with provision for release.
      Emergency hand lever to lock car to guides.
      Oil or spring bumpers.
      Air lock.

(*c*) Limits.
  Hatchway limits.
  Winding mechanism limits.
  Protection of motor.
  No voltage switch.
  Fuses.
  Circuit breaker.
  Emergency switch in car cutting off all current.
(*d*) Switch to open if cable slackens.
(*e*) Self-centering car operating switch.
(*f*) Self-closing electric brake.
(*g*) Door safety locks.

14. **Operating Devices.**
(*a*) Type of control switch.
(*b*) Number of speeds required.
(*c*) Is acceleration to be controlled automatically or by the car operator ?
(*d*) In what space is full acceleration to be obtained ?
(*e*) In what space is stop to be made from full speed ?
(*f*) Allowed excess of starting over running current.
(*g*) Allowed rise in temperature of resistance.
(*h*) Allowed carrying capacity of copper and carbon contacts.
(*i*) Is car to be operated, for test, from control panel.

15. **Extra Parts.**
(*a*) Guide lubricators.
(*b*) Spare parts for controller.
(*c*) Spare brushes for motor.
(*d*) Spare armature for motor.
(*e*) Travel recorders.

16. **Special Details.**
(*a*) Who supplies overhead grating ?
(*b*) Who supplies supports for overhead work ?
(*c*) Who supplies supports for winding engine ?
(*d*) Who supplies elevator pit ?
(*e*) Who supplies shaft ?
(*f*) Who supplies doors ?
(*g*) Who supplies engine-room enclosure ?
(*h*) Who supplies painting ?
(*i*) Who supplies electricity for tests.
(*j*) Who supplies permits and certificates ?
(*k*) Who supplies test weights and instruments ?

APPENDIX B.

HOIST ACCIDENTS IN BRITISH FACTORIES.

(From the *Annual Report of the Chief Inspector of Factories and Workshops for* 1920.)

TABLE 1.

Causation.	Fatal Accidents.	Total Injuries.
A.—Falls.		
1. Falls down hoist well when—		
(*a*) Entirely unfenced	—	6
(*b*) Fenced—single bar	3	5
Doors left open:—		
(*c*) Creeping cage	2	4
(*d*) Cage moved by some one else	—	20
(*e*) Other than (*c*) or (*d*)	—	3
(*f*) Injured person opened doors	1	10
(*g*) Automatic gates propped open or out of order	3	5
(*h*) Hoist creeping upset load when unloading	1	2
2. Fall of cage through—		
(*a*) Breaking of suspension rope	3	35
(*b*) Leaking or failure of hydraulic valve	—	—
(*c*) Other causes	—	12
3. Falls of persons or articles—		
(*a*) Getting in or out of cage in motion	1	17
(*b*) Other falls of persons out of cage	—	7
(*c*) Bodies falling out of cage and striking persons outside	1	8
(*d*) Articles falling on persons in cage through open top	—	4
(*e*) Article in cage falling on person in it	1	8
B. Crushers.		
1. Between cage and fencing of well	2	33
2. Between cage and structure of well—		
(*a*) Cage ascending—tops of doorways or floors of rooms	8	96
(*b*) Cage descending—between cage and floor of room	2	56
(*c*) Projections in well	—	27
(*d*) No projections in well	1	17
(*e*) Cage and top of well	—	7
(*f*) Cage and bottom of well	—	11
3. Crushed between truck and inside of cage	1	16
C.—Miscellaneous.		
1. Injured by—		
(*a*) Automatic gates	1	18
(*b*) Counterweight	1	8
(*c*) Gear of hoist (starting of suspension ropes, etc.)	1	23
2. Continuous hoists	—	8
3. Other causes	2	46
D.—Repairing, Cleaning or Oiling, Included in Above	2	17
Total	35	512

TABLE 2.

ELEVATOR COMPENSABLE INDUSTRIAL ACCIDENTS. NEW YORK STATE, 1 JUNE, 1914, TO 1 JULY, 1915.

(*Elevator Interlock Report, U.S.A. Bureau of Standards.*)

Cause.	Non-Fatal.		Fatal.	
	Number.	Per Cent.	Number.	Per Cent.
Caught between floor and car	113	19·8	5	10·6
Falls into shaft from floor	63	10·9	13	27·7
Caught between shaft and car	26	4·6	6	12·8
Fall of car	41	7·2	3	6·4
Struck by car (N.O.C.)[1]	36	6·3	4	8·6
Gates (N.O.C.)[1]	39	6·8	—	—
Unknown	33	5·8	1	2·1
Objects falling into shaft	61	10·0	—	—
Cables breaking	32	5·6	—	—
Caught by machinery	25	4·3	—	—
Caught by cable	25	4·3	—	—
Falls into shaft from car	13	2·3	3	6·4
Caught between car and gate	13	2·3	2	4·2
Struck by counterweight	11	1·9	3	6·4
Objects falling down shaft from car	13	2·3	—	—
Struck by car in pit	9	1·5	3	6·4
Machinery breaking	10	1·7	1	2·1
Load catching between car and shaft	6	1·0	1	2·1
Cables unwinding	4	0·7	1	2·1
Struck while on top of car	4	0·7	1	2·1
Total	577	100·0	47	100·0

[1] N.O.C. = not otherwise classified.

It should be noted that this table apparently includes all types of workshop lifts and hoists (both passenger and freight), i.e. electric, hydraulic, belt, hand, sling, etc. (Author).

TABLE 3.

PUBLIC ELEVATOR ACCIDENTS REPORTED THROUGH CLIPPING BUREAUS BY THE PUBLIC PRESS OF THE UNITED STATES, JANUARY, 1913, TO JULY, 1918.

(*Elevator Interlock Report, U.S.A. Bureau of Standards.*)

Cause.	Fatal.		Non-Fatal.	
	Number.	Per Cent.	Number.	Per Cent.
Non-shaft door accidents	107	26·4	341	60·0
Shaft door accidents				
Fell into shaft	150	36·8	121	21·2
Crushed between car and sill or frame of door	150	36·8	107	18·8
Total	407	100·0	569	100·0

TABLE 4.

PHILADELPHIA ELEVATOR ACCIDENTS.

(Elevator Interlock Report, U.S.A. Bureau of Standards.)

Type.	1914.		1915.		1916.		1917.		1918.	
	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured	Killed.
Passenger—										
Electric .	—	1	—	1	—	—	6	1	—	—
Hydraulic .	3	1	3	1	5	3	6	3	—	4
Freight—										
Electric .	7	2	14	2	8	2	5	5	5	2
Hydraulic .	6	6	4	1	9	6	5	2	2	3
Belt . .	17	4	22	4	24	2	24	7	12	12
Hand. .	—	2	3	—	—	—	3	—	2	1
Sling . .	—	—	—	—	—	—	—	1	1	1
Total .	33	16	46	9	46	13	49	19	22	23

APPENDIX C.

REGULATIONS RELATING TO THE INSTALLATION, OPERATION, AND MAINTENANCE OF LIFTS.

Desirability of Regulations.—Although every taxpayer is very loath to suggest any extension to existing regulations, bye-laws, etc., and a corresponding increase in the numerical strength of inspectors, yet it is obvious, from the accidents reported in the daily papers, that lifts are a source of danger, and that, from the point of view of public safety, the installation, operation, and maintenance of lifts requires closer supervision than it has hitherto received.

In America, where Mr. Thomas E. Browne states $12,000,000, or £2,500,000, was spent during the year 1903 on the installation of passenger and goods lifts, regulations are in force in the principal states and cities, and two codes are reprinted below as typical of general practice in this respect.

I.

BUILDING ORDINANCE OF THE CITY OF CHICAGO, U.S.A.

Effective, January, 1911. Amended to 1916. Article XXI., "Elevators and their Enclosing Walls."

681. **Elevators—Passenger and Freight—Permit for Construction—Fee—Penalty.**—(*a*) Before proceeding with the construction or alteration of any passenger or freight elevator, except such as are hereinafter specially exempted from the provisions of this chapter, a permit for such construction or alteration shall be obtained from the Commissioner of Buildings either by the owner or agent of the building in which such elevator is to be constructed, or in which such alterations are to be made, or by the contractor who is about to construct or alter such elevator.

(*b*) It shall be unlawful for any such owner, agent, or contractor to permit or allow the construction of any such elevator

or the making of such alterations, or to proceed with or in or about any of the work of construction or alteration of any such elevator until such permit shall first have been obtained. Such permit shall be issued by the Commissioner of Buildings after application shall have been made to him therefor by any such owner, agent, or contractor, specifying the number and kind of elevators which it is desired to construct, or the nature of the alterations to be made, and the location of the building or structure in which the same is or are to be placed or made. Such application shall be accompanied with such plans and specifications as shall be necessary to advise and inform said Commissioner of the plan of construction, type of elevator, kind of alterations, and the location thereof. If such plans and specifications shall show that such elevator or elevators is or are to be constructed or erected or altered in conformity with the provisions of this chapter, the Commissioner shall approve the same and shall issue a permit to such applicant upon the payment by such applicant of a fee of two dollars for each elevator to be constructed, erected, or altered, and such fee shall be known as a permit fee, and shall not be held to cover the cost of any inspection which shall at any time thereafter be made of such elevator or elevators when constructed, or of any alterations made.

(*c*) All contractors or persons, firms, or corporations, engaged in the manufacture and work of installing iron doors on passenger or freight elevators, or of installing wire-work enclosures around elevators shall secure a permit from the Commissioner of Buildings for the work on each such elevator, the fee for which shall be two dollars for each elevator.

(*d*) It shall be unlawful for any person, firm, or corporation, either as owner, lessee, contractor, or agent of any building or structure in which any elevator or e'evators are to be constructed or altered to proceed with said work without securing a permit as herein required for such construction or alteration, and no such permit shall be issued until such person, firm, or corporation, lessee, contractor, or agent shall have complied with all the requirements of this chapter.

682. **Enclosure of Elevator Shafts in Non-Fireproof Buildings.**—In all non-fireproof buildings hereafter erected all passenger elevators, and all freight elevators, except such as are expressly exempted by this chapter, shall be enclosed in a wall of brick, tile, or such incombustible material as may, from time to time, be approved by the Commissioner of Buildings as proper and suitable for the purpose; such enclosure shall extend from the

foundation to the roof of such building, and shall be supported independently of the floor construction; provided, further, however, that the provisions of this section shall not apply to any non-fireproof building which is equipped throughout on every floor and in every room thereof, and in all stairways, platforms, elevator shafts, elevator hoistways, and well holes with an automatic sprinkler system approved by the Fire Marshal.

683. **Enclosure of Pits and Shafts in Basements.**—In all buildings heretofore or hereafter erected, whenever any elevator shaft extends down into a basement or sub-basement, that portion thereof extending below the street level shall be enclosed in walls of brick, tile, or other fireproof material, and the door openings in such enclosure shall be protected by incombustible doors. Where such elevator shafts do not extend down into the basement they shall be provided with fireproof pits at the lowermost floor level above which they serve, and such pits shall have no openings except for cables or other elevator equipment.

684. **Enclosure of Dumb Waiter Shafts—Materials.**—In all non-fireproof buildings hereafter erected, the dumb waiter shafts shall be enclosed with brick, tile, reinforced concrete, or cement plaster not less than 2 ins. thick, or metal studs and lath.

685. **Doors—On Elevators.**—In all elevator shafts which are herein required to be enclosed with fireproof walls, the door openings shall be equipped with doors of incombustible material, which shall be made to open from the outside by means of a key or other device satisfactory to the Commissioner of Buildings.

686. **Hatch Doors—Freight Elevators.**—Elevators, used exclusively as freight elevators, constructed and in operation at the time of the passage of this ordinance need not have enclosing walls, but in all such cases there shall be at every floor through which such freight elevators pass automatic hatch closers or automatic doors, made in such manner that they will fully close each well hole when the temperature in such well hole exceeds 140 degrees Fahrenheit; and it shall be the duty of the owner, agent, or person in possession, charge, or control of a building in which such elevator is maintained to keep such hatch closers or doors at all times in good working order. Such automatic hatch closers shall be examined by the Commissioner of Buildings and the Fire Marshal, and if said officials shall find that such doors will automatically close when the temperature at or near such doors exceeds 140 degrees Fahrenheit, and that the conditions of construction and operation of such doors or hatch closers are such

that there is no reasonable probability of their getting out of order and failing to operate when required, and that in their construction or operation there is nothing that is likely to cause accidents to or interference with the elevator service in such hatch holes which they were intended to close, and that the building in which such freight elevator is in use is equipped with stairways, fire escapes, and passenger elevators sufficient to offer ample means of escape from such building in case of fire, for all persons employed, or for all persons in such building, then, and in such case only, shall the use of such hatch doors or closers be permitted. All freight elevators in non-fireproof buildings shall comply with the preceding requirements of this section, or shall have enclosing walls of incombustible or fireproof construction. Such elevators are to be inspected semi-annually and oftener when, in the opinion of the Commissioner of Buildings, such inspection is necessary, and such fees shall be paid for said inspection as otherwise provided in said chapter.

*687. **Safety Device.**—(*a*) Every passenger and freight elevator now in operation or hereafter installed, except such as are hereinafter exempted from the provisions of this chapter, shall be provided with a speed governor and such other efficient device to secure the safe operation of such passenger or freight elevator, and to prevent the cab or car of such elevator from falling, and to secure the safety of the cab or car and its load in case it does fail, as may be required by the Commissioner of Buildings. Such speed governor and other devices shall be subjected to such a practical test as may be determined by the Commissioner of Buildings for the purpose of ascertaining the efficiency of such safety device.

(*b*) It shall be the duty of the Commissioner of Buildings to make such test of each and every device upon all elevators, and no elevator shall be permitted to be run until such test has been made.

(*c*) *That whenever any accident shall occur causing injury to any person affecting life or limb, in or about an elevator, or while getting on or off an elevator, or in any way impairing the safety of the elevator, the same shall be reported at once by the owner, superintendent, lessee, or manager of the building, or the operator of the elevator, to the Commissioner of Buildings. No broken or damaged part of such elevator shall be moved or displaced, or repairs made thereon, nor shall said elevator be operated until an investigation*

* Amended (by adding paragraphs (*c*), (*d*), and (*e*)), April 28, 1913.

into such accident has been made by the Commissioner of Buildings or his duly authorised agent. A full report in writing of the result of each investigation shall be filed in the Department of Buildings, and the Commissioner of Buildings shall keep a complete record of all such accidents and reports thereon.

(*d*) *It shall be unlawful for any operator of any elevator in the City of Chicago wherein passengers are conveyed to start such elevator until all doors of such elevator and leading into such elevator shall be closed. It shall be unlawful for any such operator to open the doors of such elevator until said elevator has come to a full stop.*

(*e*) *Any person violating any of the provisions of this section shall be fined not less than twenty-five dollars nor more than two hundred dollars for each offence.*

*688. **Safeguards for Elevators.**—(*a*) Where the counterweights travel in the same hatchway with an elevator car, the portion of the car contiguous to the weights shall be protected from the top to the bottom of the car by a suitable guard.

(*b*) All freight elevators shall be provided with a guard at least 6 ft. high. All elevator cabs or cars, whether used for freight or passengers, shall be provided with some device whereby the car or cab may be held in the event of accident to the shipper rope or hoisting machinery or controlling apparatus.

(*c*) No passenger elevator hereafter erected shall be installed with a freight compartment either below or above the car.

(*d*) *All hoistways, hatchways, elevator wells, and wheel holes in any building, whether occupied or vacant, shall be securely fenced, enclosed or otherwise safely protected, and it shall be the duty of the owner, occupant, or agent of any such building to keep all such means of protection closed at all times, except when it is necessary to have the same open, in order that the said hatchways, elevators, or hoisting apparatus may be used.*

(*e*) It shall be unlawful to erect or maintain an elevator where such elevator or its counterweight descends into any passageway or thoroughfare.

(*f*) There shall be directly under the sheaves at the top of every elevator hatchway, a grating of steel or heavy wire mesh properly supported by steel or iron, and capable of sustaining a load of not less than 500 lbs.

(*g*) All counterweights hereafter installed shall have their component parts so fastened together as to prevent any piece or pieces from becoming detached from the guides should the counterweights be accidentally drawn to the top of the hatchway.

* Amended February 2, 1914.

(*h*) Where drum counterweight cables run through or pass by the car counterweights to weights underneath, they shall be provided with a suitable covering to prevent their chafing and wearing on the counterweights.

(*i*) Where elevators other than hand hoists and sidewalk elevators are not enclosed with fireproof or incombustible material, as is elsewhere herein specified in this Article, the well hole of such elevator shall be enclosed with a wire guard not less than 6 ft. high. The counterweights and the immediate space through which they travel must be protected from the floor to the ceiling with a wire guard, or with other incombustible material. There must be on all elevators hereafter constructed a clear space of not less than 2 ft. between the bottom of the hatchway and the level of the lower floor landing when the car is at its lowest position, and there must be a clearance of at least 4 ft. from the top of the cross-beam of the car to the lower side of the grating under the overhead sheaves. Whenever there is conflict in regard to the manner of enclosing any elevator shaft or portion thereof between this section and Sections 682, 683, and 684, the provisions of the latter sections shall prevail.

(*j*) All passenger and freight elevators hereafter installed, except sidewalk or hand elevators, shall have an artificial travelling gas or electric light attached to the car, and maintained in good working condition.

(*k*) All power-driven elevators hereafter constructed or installed shall have at least two hoisting cables for the cage, and two cables for each counterweight. The lifting and counterweight cables shall have at least one full turn of the cable on the drum when the car has run its limit.

(*l*) It shall be unlawful to change a hand hoist to a power-driven elevator without first making application to the Commissioner of Buildings for a permit for such change, and it shall be unlawful to connect an electric motor or any other appliance to the hand elevator machinery without the approval of the Commissioner of Buildings.

(*m*) All elevators, except hand elevators operated by a pulley rope and sidewalk ram or chain hoist elevators, and elevators used in tunnels for freight service only, shall be equipped with a safety speed governor.

(*n*) Where ropes or cables are used to operate safety devices, a weight shall be properly attached to the same in such a manner as to ensure the necessary tension on such rope or cables for proper performance of the safety devices.

(*o*) All elevators propelled by electricity shall be provided with an additional device not operated by a link belt or sprocket chain which will automatically stop the elevator machinery when the car has reached its limit of travel. It shall be unlawful to construct or maintain any elevator equipped with a sprocket chain or link belt device or devices connecting the operating device and controller.

(*p*) An emergency switch which will disconnect the current shall be provided in all passenger elevators hereafter installed which are operated by an electric controller car switch and such cars shall be so constructed that they will automatically stop when the current is disconnected.

(*q*) The underside of the floors or other parts of a building which project into passenger elevator shafts shall be equipped with a smooth steel guard curved and sloped from the enclosure of said elevator to the edge of such projection for the width of the door to such elevator car, and the slope of the guard plate shall not be less than sixty degrees with the horizon.

(*r*) The provisions of this section requiring the equipment of elevators with safety devices shall not apply to any hand hoists, elevator, or hoist used solely for hoisting materials or tools in any building in course of construction, but the Commissioner of Buildings shall make such reasonable requirements as he may deem necessary for public safety in the operation of such hand hoists, elevators, or hoists used solely for hoisting materials or tools in such buildings while under construction.

689. **Inspection—Test—Certificate to be Posted.**—(*a*) Every elevator now in operation, or which may be hereafter installed together with the hoistway and all equipment thereof, shall be inspected under and by the authority of the Commissioner of Buildings at least once every six months, and in no case shall any new elevator be placed in operation until an inspection of the same has been made.

(*b*) It shall be the duty of every owner or agent, lessee, or occupant of any building wherein any elevator is installed and the person in charge or control of any elevator to permit the making of a test and inspection of such elevator or elevators and all devices used in connection therewith upon demand being made by the Commissioner of Buildings, or by a duly authorised Elevator Inspector, within five days after such demand has been made.

(*c*) Whenever any such elevator has been inspected and the tests herein required shall have been made of all safety devices with which such elevator is required to be equipped, and the result

of such inspection and tests shows such elevator to be in good condition, satisfactory to the Commissioner of Buildings, and that such safety devices have been provided in accordance with the requirements of this chapter, and are in good working condition and in good repair, it shall be the duty of the Commissioner of Buildings to issue or cause to be issued a certificate setting forth the result of such inspection and tests, and containing the date of inspection, the weight which the elevator will safely carry, and a statement to the effect that the shaft doors, hoistway, and all equipment, including safety devices, are constructed in accordance with the provisions of this chapter, upon the payment of the inspection fee required by this chapter.

(*d*) It shall be the joint duty of the owner, agent, lessee, or occupant of the building in which such elevator is located, and of each person in charge or control of such elevator to frame the certificate, and place same in a conspicuous place in each elevator.

(*e*) The words "safe condition" in this section shall mean that it is safe for any load up to the amount of weight named in such certificate.

(*f*) Where the result of such inspection or tests shall show such elevator to be in an unsafe condition or in bad repair, or shall show that the safety devices, or any of them, which are required by this chapter, have not been installed, or if installed, are not in good working order or not in good repair, such certificate shall not be issued until such elevator, its hoistway and its equipment or such device or devices shall have been put in good working order, satisfactory to the Commissioner of Buildings. The inspection fees herein required shall be paid either at the time application is made for inspection or upon the completion of such inspection and tests.

690. **Power of Commissioner to Stop Operation of Elevators.**—(*a*) Whenever any building or elevator inspector finds any passenger or freight elevator or any of its running parts or automatic devices or other equipment out of order, or in an unsafe condition, he shall immediately report the same to the Commissioner of Buildings, together with a statement of all the facts relating to the condition of such elevator or elevators.

(*b*) It shall be the duty of the Commissioner of Buildings upon receiving from any inspector a report of the unsafe condition of any elevator, to order and cause such elevator not to be used until the same shall have been placed in a safe condition, and it shall be unlawful for any owner, agent, lessee, or occupant of any building, wherein any such passenger or freight elevator is located

within the city, to permit or allow any such elevator to be used after the receipt of a notice in writing from the Commissioner of Buildings that any such elevator is out of order, or is in an unsafe condition, and until said elevator has been put in a safe and proper condition as required by the provisions of this chapter.

II.

CITY OF NEW YORK.

Effective in the Borough of Manhattan, September 1, 1911.

1. **Definition and Application.**—The term "elevator" as used in these regulations shall include all elevators or lifts used for the carrying of passengers or employees. The term "dumb waiter" shall include such special form of elevator, the dimensions of which do not exceed 9 sq. ft. in horizontal section, and 4 ft. in height, and which is used for the conveyance of small packages and merchandise. So far as practicable, these regulations shall also apply to escalators. Where freight elevators are placed within the same shaft enclosure as passenger elevators, such elevators must conform in all particulars to the regulations for the construction, inspection, and operation of passenger elevators. All other freight elevators must comply with sections 3, 4, 6, 7, 10, 12, 13, 14, 15, 17, 18, 19, 20, 21, and 22 of the Regulations for Passenger Elevators. Any hand-power elevator having a rise of more than 35 ft. shall comply with all the requirements of these regulations. No belt elevators driven from a countershaft shall be installed for passenger service.

2. **Inspection.**—All elevators must be inspected as often as possible by an Inspector of the Bureau of Buildings, known and designated as Inspector of Elevators, in accordance with the rules and regulations of the Bureau prescibing the duties and governing the actions of the employees.

3. **Approval and Tests for New Installations and Alterations.**—Before any elevator shall hereafter be installed or altered in any building, the owner or his agent, architect or contractor shall submit, on appropriate blanks furnished therefor, to the Superintendent of Buildings an application in triplicate stating the construction and mode of operation of such elevator to be installed or altered and shall obtain his approval therefor. This application shall be accompanied by such plans and drawings as may be necessary. Before any such elevator shall be put

of such inspection and tests shows such elevator to be in good condition, satisfactory to the Commissioner of Buildings, and that such safety devices have been provided in accordance with the requirements of this chapter, and are in good working condition and in good repair, it shall be the duty of the Commissioner of Buildings to issue or cause to be issued a certificate setting forth the result of such inspection and tests, and containing the date of inspection, the weight which the elevator will safely carry, and a statement to the effect that the shaft doors, hoistway, and all equipment, including safety devices, are constructed in accordance with the provisions of this chapter, upon the payment of the inspection fee required by this chapter.

(*d*) It shall be the joint duty of the owner, agent, lessee, or occupant of the building in which such elevator is located, and of each person in charge or control of such elevator to frame the certificate, and place same in a conspicuous place in each elevator.

(*e*) The words "safe condition" in this section shall mean that it is safe for any load up to the amount of weight named in such certificate.

(*f*) Where the result of such inspection or tests shall show such elevator to be in an unsafe condition or in bad repair, or shall show that the safety devices, or any of them, which are required by this chapter, have not been installed, or if installed, are not in good working order or not in good repair, such certificate shall not be issued until such elevator, its hoistway and its equipment or such device or devices shall have been put in good working order, satisfactory to the Commissioner of Buildings. The inspection fees herein required shall be paid either at the time application is made for inspection or upon the completion of such inspection and tests.

690. **Power of Commissioner to Stop Operation of Elevators.**—(*a*) Whenever any building or elevator inspector finds any passenger or freight elevator or any of its running parts or automatic devices or other equipment out of order, or in an unsafe condition, he shall immediately report the same to the Commissioner of Buildings, together with a statement of all the facts relating to the condition of such elevator or elevators.

(*b*) It shall be the duty of the Commissioner of Buildings upon receiving from any inspector a report of the unsafe condition of any elevator, to order and cause such elevator not to be used until the same shall have been placed in a safe condition, and it shall be unlawful for any owner, agent, lessee, or occupant of any building, wherein any such passenger or freight elevator is located

substantial material and construction, properly braced and carried the full height of openings, and there shall not be more than $1\frac{1}{2}$ in. space between any two members of said grille work except where plain straight bars are used, not filled in with scroll, when there shall not be more than 1 in. space between members.

8. **Landing Door Locks.**—All doors or gates leading to any elevator shaft shall be locked or bolted on the shaft side so as to be opened only by the operator of the car, and said shaft doors or gates and car gates shall be closed before the car is put in motion.

9. **Car Gates.**—All entrances to elevator cars must be provided with substantial folding or sliding gates or doors, and where floor tracks are used the same must be countersunk. All folding gates over 3 ft. wide at entrance to shaft or car shall have top and bottom centre braces.

10. **Counterweights (Construction of).** — All counterweights shall have their sections strongly bolted together. There shall not be less than 3 ft. clearance between the top of counterweights and the underside of overhead beams when the car is resting on the bumpers. No continuous forged straps shall be permitted on counterweights.

11. **Counterweights (Protection of).** — Where counterweights run in the same shaft as the car they must be protected with a substantial screen of iron from the top of rail to a point 15 ft. below, except where the plunger or traction type of elevator is used.

12. **Safety Gear.**—All elevators, except direct plunger elevators and freight elevators having a rise of 15 ft. or less, shall have a governor or speed regulator properly connected to the safety devices on the car, in such a manner that the car will be brought to rest with an easy and gradual stop, or in a distance not greater than 8 ft. for a speed of 700 ft. per minute, except that on elevators having a speed of 100 ft. per minute or less safeties of the instantaneous type may be used. Every elevator operating on alternating-current electricity shall be equipped with an electric mechanical brake, or some such device as will ensure the brake being applied at any time should the current be interrupted from the service. All electric car controlling devices shall be self-centering and self-locking in inoperative position. All hoisting machines of the drum type shall have an automatic slack cable device that will stop the machine if the hoist or drum weight cables shall become slack

from any cause. All elevators shall have upper and lower limit devices on the machine or in the shaft. *No elevator shall be used for the carrying of safes or other material of a greater weight than the normal lifting power of such elevator, unless the car is equipped with a locking device which will hold it fixed at any landing independent of the rope while such safe or other material is being loaded or unloaded.*

13. **Car to be of Fire-resisting Material.**—The car of all elevators must be constructed of incombustible materials, except that interior trim and flooring may be of hard-wood. There shall be not more than $1\frac{1}{4}$ in. space between the floor of the car and the floor saddles, and where the saddles project into the shaft the same shall be properly bevelled on the underside. The underside of the car must be of incombustible materials. Cars for all elevators shall be properly lighted.

14. **Guide Rails.**—All guide rails for both car and counterweights shall be of iron or steel, and shall be fastened to the sides of the shaft with wrought or cast-iron brackets, so spaced that the guide rails will be rigid.

15. **Lifting Cables.**—There shall be not less than two cables independently connected to the car and to each set of counterweights. The lifting and weight cables shall have at least one full turn of the cable on the drum when they have reached the limit of travel. Such cables shall be of a diameter to ensure a factor of safety of five. All cables used in the operation of elevators shall be of steel, iron or "Marlin" covered. Where overhead machines are installed the use of equaliser arms will be permitted on the car and counterweights.

16. **Freight Compartment on Car Prohibited.**—No elevator shall be permitted to have attached above, below, or on the inside of the car a freight compartment or similar device.

17. **Overhead Grating.**—Immediately under the sheaves at the top of every elevator shaft in any building there shall be provided and placed a substantial grating of iron or steel having not more than $1\frac{1}{2}$ in. space between any two members of said grating, and of such construction as shall be approved by the Bureau of Buildings.

18. **Overtravel Space.**—A clear space of not less than 3 ft. must be provided between the bottom of the shaft and the lowest point of the underside of the car floor when the car is at its lowest landing, and between the top of the crosshead of the car and the underside of the overhead grating when the car is at its top landing, provided that for elevators of greater speed than 350 ft.

per minute, the distance between the top of the crosshead of the car and the underside of the overhead grating, when the car is at its top landing, shall be not less than 5 ft., except in the case of elevators where the rise does not exceed 30 ft. and the speed of the elevator is not more than 100 ft. per minute, such clear space at the top of the shaft shall be not less than 2 ft. between the top of the car and the underside of the overhead grating when the car is at its top landing.

19. **Engine-room.**—All parts of the elevator machinery must be properly enclosed by suitable partitions of incombustible materials, and such enclosures must be lighted. Free and safe access must be provided to all parts of elevator machinery. Where the machine is located at the bottom of the shaft the same shall be protected with a substantial pit pan.

20. **Car Speed.**—The speed of all elevators must not exceed 500 ft. per minute, except that express elevators may run 700 ft. per minute for that portion of the shaft in which no intermediate stops are made. Express elevators shall mean only such elevators as run 80 ft. or more without stop. The speed of mechanically controlled electric elevators must not exceed 150 ft. per minute.

21. **Buffers.**—At the bottom of all elevator shafts there shall be placed substantial buffer springs for car and counterweights. Where the car does not travel to the bottom of the shaft the bumper beams shall be supported independent of the car rails. All plunger or traction type of elevators shall be provided with substantial oil buffers at the bottom of the shaft for both car and counterweights.

22. **Beams.**—The carrying beams for all machinery shall be of wrought iron or steel.

23. **Escape Door.**—Every passenger elevator shall have a trap door in the top of the car of such a size as to afford easy egress for passengers, or where two cars are in the same shaft such means of egress may be provided in the side of each car.

24. **Penalty for Non-Compliance.**—Any infraction of these regulations or failure to comply with their provisions after due notice from the Superintendent of Buildings shall be treated the same as a violation of the Building Code, and shall subject the owner to the same penalties as prescribed in section 150 of the Building Code for such violation.

APPENDIX D.

TYPICAL ENGLISH LIFT INSTALLATIONS.

Building.	No. of Lifts Installed.	Dimensions of Car.	Area of Car Floor (sq. ft.)	Live Load (lbs.)	Car Passenger Capacity.	Floors Served.	Total Travel (ft.).	Rated Road Speed. ft./min.	B.H.P.	Electricity Supply.	Method of Drive.	Reduction Gear.	Method of Control.
Regent Palace Hotel, London (passenger)	5	4' 6" × 5' 6" (average)	24·75	1680	11	10 to 13	83' 6" to 122' 3"	300	15	D.C.	Vee sheave	Single worm	Car switch
Cunard Building, Liverpool (passenger)	9	4' 6" × 5' 0"	22·5	1680	11	4 to 8	81' to 106' 9"	300	16	D.C.	Drum	Double screw	Car switch
Do. Do.	1	Do.	Do.	4000	—	9	120' 9"	100	12	Do.	Do.	Do.	Do.
Selfridge House, London Old Building (passeng'r)	9	6' 0" × 6' 0"	36	2240	15	—	68'-96'	300	20	D.C.	Drum	Double screw	Car switch
New Do.	12	6' 0" × 6' 0"	36	2240	15	8	82	300	25	Do.	V. sheave	Single worm	Do.
Royal Liver Building, Liverpool (passenger)	15	4' 4½" × 5' 5"	23	1800	11	11 (3)	148	300	25 at 800 R.P.M.	D.C.	V. sheave	—	Car switch
						7 (6)	—	400/275		Do.	Do.	—	Do.
						3 (2)	—	400/275		Do.	Do.	—	Do.
						3 and 4 (2)	163	400/275		Do.	Do.	—	Do.
						6 (1)	208	400/275		Do.	Do.	—	Do.
Messrs. Lewis's, Manchester	10	6' 6" × 5' 5" / 4' 9" × 5' 9"	35·5 / 27·5	2240	—	7 / 8	85 / 97	350	25	D.C.	V. sheave	—	Car switch
Adelphi Hotel, Liverpool	4	—	25	1500	10	2 for 9	103	300	16	D.C.	Drum	Single worm	Car switch
Do. (baggage)	1	—	—	2470	—	2 for 13	150	200	18	Do.	Do.	Do.	Do.
Residence (passenger)	1	2' 11" × 2' 11"	8·5	448	3	7	42	120	2·25	480 D.C.	V. sheave	Single bottom	Push button
Do. Do.	1	2' 9" × 1' 7¼"	4·4	448	2	3	44' 6"	100	2	400 D.C.	Do.	Single top	Do.
Do. Do.	1	2' 10" × 4' 2"	11·8	500	5	5	35	100	2·1	Do.	Do.	Do.	Do.
Warehouse (goods)	1	5' 0" × 3' 3"	16·25	1120	—	6	75' 9"	115	5·5	440 D.C.	V. sheave	Single top	Car switch
Factory (goods)	1	4' 0" × 4' 4"	16	672	—	4	35	100	3·0	480 D.C.	V. sheave	Single top	Car switch
Do. Do.	3	7' 0" × 7' 0"	49	3360	—	3	23' 6"	100	14	415 3 ph. 50 periods	Do.	Do.	Push button
Garage (goods)	1	4' 6" × 7' 0"	31·5	3360	—	3	29' 6"	80	11	400 D.C.	V. sheave	Single top	Car switch

(The above schedule has been compiled from data kindly supplied by Messrs. Marryat & Scott, Ltd., and Messrs. Waygood-Otis, Ltd.)

APPENDIX E.

ELECTRIC LIFT ENQUIRY FORM.

(By the courtesy of Messrs. R. A. Evans, Ltd.)

1 Type.	Is lift for (*a*) Passengers (*b*) Goods only (*c*) Passenger and goods ?
2 Load.	What is the maximum load to be raised (in lbs.) or the number of passengers to be carried ? (If possible state whether the lift will be used very little, normal or constantly. If a goods lift the nature of the goods to be handled.)
3 Speed.	Approximate speed required in feet per minute ?
4 Control.	What system of control is required ? (*a*) Hand-rope. (*b*) Car switch. (*c*) Semi-automatic push button (up, down and stop). (*d*) Fully automatic push button. In case of a lift for goods only, which of the above outside controls is required ?
5 Position of Machine.	Where is the machine to be placed ? (*a*) At the top directly over well ? (*b*) At the bottom, at the back or side ? (*c*) At any intermediate level ?
6 Type of Car.	If for passengers, is a simple or elaborate design required, and what kind of wood is to be used ? If for goods is any special lining required ? Is the car to be open through or one side only ?
7 Height of Travel.	(*a*) What is the total travel of the lift in feet (i.e. the distance from the lowest to the highest level the lift is required to serve) ? (*b*) How many landings are to be served ? (*c*) Give distance in feet from top floor level to underside of roof or ceiling. (*d*) State the total number of openings to the well.

8 Car.	What size of car is required? Give inside dimensions, stating width and depth, the width being the open side.	
9 Size of Lift Well.	If well is already formed or size determined, give that size.	
10 Type of Lift Well.	Is the lift well of brick or concrete, a stairwell, a well trimmed through floor, or in a steel structure?	
11 Electric Supply Available.	If continuous, state voltage. If alternating, state :— (*a*) Voltage. (*b*) Phases. (*c*) Periods.	
12 Guides.	What type of guides are required :— (*a*) For the car: steel or wood? (*b*) For the balance weight: steel or wood?	
13 Gates on Car.	Is the car to be fitted with collapsible gate?	
14 Gates on Landings.	If required state whether :— (*a*) Collapsible steel. (*b*) Single wooden door (hinged). (*c*) Double wooden door (hinged).	
15 Enclosure.	Is any enclosure work required? If so state what type.	
16 Style of Premises.	Please state whether factory, warehouse, hotel, office building, hospital, etc.	
17 Erection.	Are we to erect or deliver only?	
18 Date of Delivery Required.		

NOTE :—If possible please forward drawing of lift well with plan and elevation.

SPECIAL REQUIREMENTS.

APPENDIX F.

REPORT OF INSPECTION OF LIFT.

(By the courtesy of Messrs. R. A. Evans, Ltd.)

MOTOR.	
CONTROLLER.	
GEAR.	
LIFTING ROPES.	
CAGE AND SAFETY GEAR.	
GUIDES.	
BALANCE WEIGHT.	
OVERHEAD WHEELS.	
BRAKE.	
LIMIT SWITCHES.	
OPERATING HAND-ROPE.	
GATES.	
GATE LOCKS.	
ELECTRIC BELL.	

REMARKS :

Date of Inspection.	*Inspector.*	

APPENDIX G.

ELECTRIC LIFT TEST SHEET.

(By the Courtesy of Messrs. R. A. Evans, Ltd.)

Name of Customer..
Lift fixed at..
Date of Tests..Tests made by...
Customer's Representative present during Tests..
Specified Load..Speed..Travel..
System of Control..
Position of Lift Machine..

CURRENT IN AMPERES (Ammeter connected in Main) AND VOLTAGES.							TIME IN SECONDS.	
UP.				DOWN.				
Load.	Starting.	Running.	Volts.	Starting.	Running.	Volts.	UP.	DOWN.

Notes.—(*a*) Before taking any current or speed tests see that the lift is balanced so that the balance weight is equal to the weight of the car, *plus half the maximum specified load of lift.*

(*b*) Current readings should be taken for NO LOAD, $\frac{1}{4}$ LOAD, $\frac{1}{2}$ LOAD, $\frac{3}{4}$ LOAD and FULL LOAD, and in each case it is important that definitely known weights be used for testing, but when these cannot possibly be obtained and the loads are in the form of passengers, state the number of passengers and their weight as accurately as possible.

(*c*) For each load test, state the average current readings for say 4 journeys and to obtain the most accurate results the ammeter should be watched during the whole of the time the lift is running.

(*d*) The time in seconds for one UP or DOWN journey should be taken from the time the motor commences to revolve to the time it stops.

SUBSIDIARY CIRCUITS (Currents and Voltage).			
	Time taken.	Amperes.	Voltage.
MOTOR SHUNT			
BRAKE COIL			
CONTROLLER			

Note.—Tests should be taken and particulars stated when Motor, Brake Coil and Controller are cold, and the second set of tests should be taken at the end of main tests.

Insulation Tests.

All in circuit..................................Megohms. Motor Armature.............................Megohms.
Motor Field Windings........................Megohms. Controller only.......................Megohms.
Control Wiring including Gate Locks.................Megohms. Brake...............Megohms.

Safety Gear on Car.

Method of Test..

....

....

Number of Times tested..
Amount of Slip..
General Observations of Test..

....

....

Clearances.

When the floor of Car is level with top floor level, state the exact distance between the top face of suspension channels across top of Car and the under face of the girders carrying the lift machine or the overhead wheels :

....

Also when the Car is in the same position as above stated, give the distance between the bottom of the Balance Weight and the pit bottom :

....

When the Car is level with the lowest level or landing, state the exact distance between the top of Balance Weight and the overhead joists :

....

What is the exact depth of the Pit ?...
What type of buffers are provided for the Car ?..
,, ,, ,, ,, ,, ,, Balance Weight ?..

Stopping Tests.

When the Electro-Mechanical Brake and Dynamic Brake have been properly adjusted state what difference (in inches) there is between stopping at NO load and FULL load when the lift is allowed to run a full journey up and a full journey down and in both cases allowed to stop automatically by the operation of the control circuit limit switches.

....

....

....

....

....

....

Fuses.

Apart from the Main Fuse or Fuses provided by the Supply Co. which will be fixed near to their meter the following fuses should also be provided:

"A"—Fuse or Fuses near to Main Switch at the Meter end of the Main Wiring.
"B"— ,, ,, ,, Secondary Main Switch at the Motor end of the Main Wiring.
"C"—Fuses on the Controller placed in the *Control Circuit*.

B"—Fuse or Fuses should be such as to afford adequate protection for the Motor.
A '— " " " approx. 25% larger capacity than "B."
"C"—Fuses should be of.........Amp. capacity.

State below the size and type of all the fuses which have been fitted and left in the various fuse boxes and fuse holders after tests have been completed :

"A"..

"B"..

"C"..

Exact Height of Travel.

Measure with steel tape or other reliable means the exact distance from lowest to highest landings and give this as follows :..

Earthing.

Examine carefully all parts to which current is taken such as Motor, Controller, Brake Magnet, Main Switch and Fuses, Limit Switches, Car Switch, Push Buttons, Gate Locks, Junction Boxes, etc., and report whether all metal casings or enclosures for such parts are efficiently "Earthed."

....

....

....

Motor Name-Plate.

Give particulars of what is stated on Motor Name-plate :

....

....

....

....

Controller Name-Plate.

Give particulars of what is stated on Controller Name-plate :

....

....

....

....

Car Name-Plate.

Give particulars of what is stated on Name-plate in the Car :

....

....

Electricity Supply.

State name of Company or Corporation who are supplying the current and give particulars of the supply :

....

....

Motor Brushes.

State number, particulars and sizes of motor brushes with sketch :

....

....

....

....

General Observations.

After tests have been carried out make a general inspection of all working parts and state the condition of same, also give particulars regarding the operation and running of the lift and make any further remarks which you deem necessary or useful for future reference.

....

....

....

....

INDEX.

PRINTED IN GREAT BRITAIN AT THE ABERDEEN UNIVERSITY PRESS, ABERDEEN